METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 59 No. 351 JANUARY, 1959 Monthly: Two Shillings and Sixpence

NEWTON CHAMBERS

Important new developments

NEWTON CHAMBERS are now better equipped than ever before to offer a comprehensive service to the steel industry. Extensions to our constructional shops with the provision of new equipment enable us to make even larger and more intricate fabrications.

We bring to the service of the steel industry years of specialised design and manufacture of steelworks plant and equipment and we are to-day one of the largest suppliers of steelworks ancillary plant, including ladles up to 300-tons capacity.

RIGHT: One of many Steel Casting Ladles supplied to John Summers & Sons Limited.

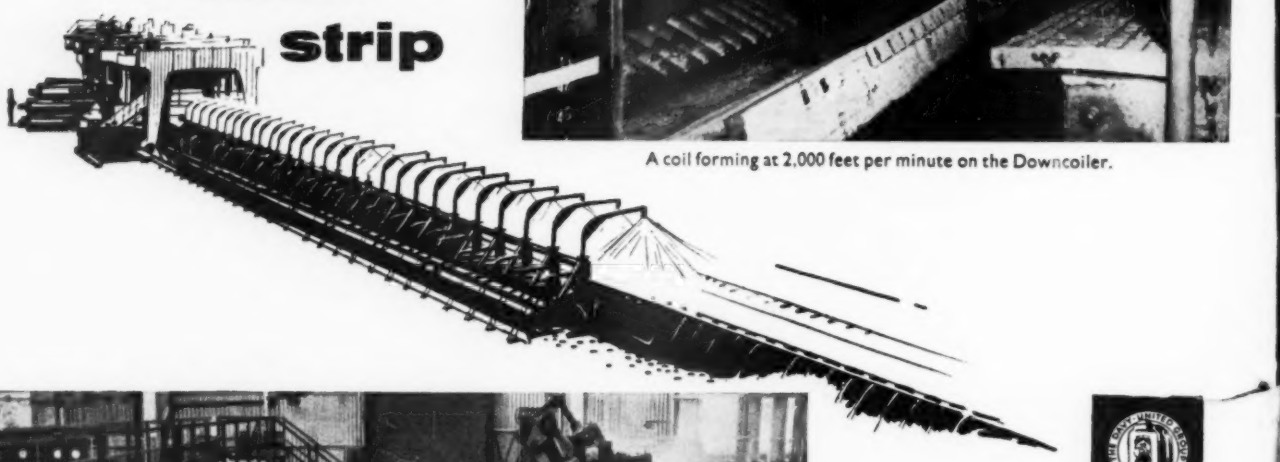
ENGINEERS OF PROGRESS

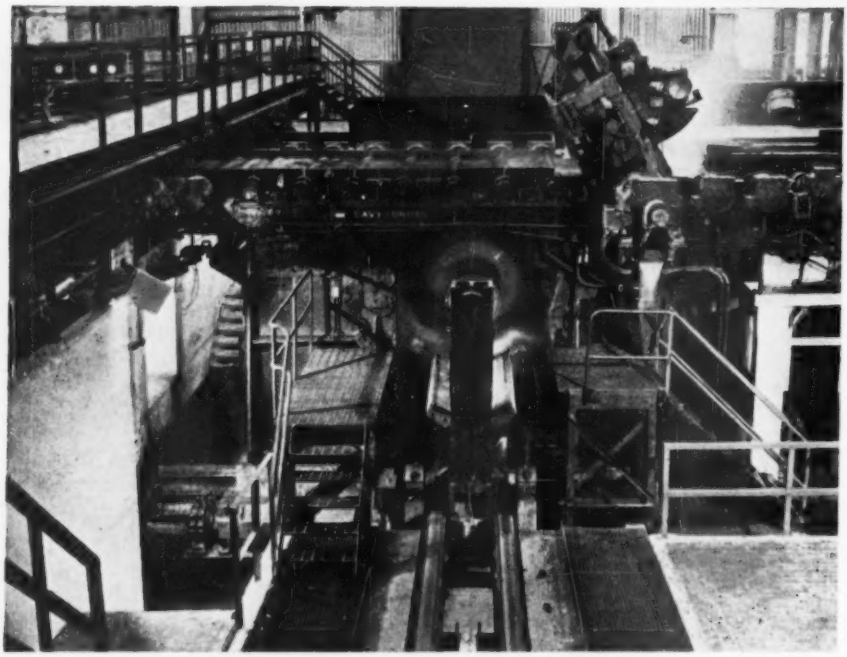
Newton Chambers ENGINEERING DIVISION

NEWTON CHAMBERS & COMPANY LIMITED · THORNCLIFFE · SHEFFIELD

Hot Downcoiler for wide strip

A coil forming at 2,000 feet per minute on the Downcoiler.





From the control pulpit. Maximum weight of coil handled is 30,000 lbs., while strip width varies between 27" minimum and 74" maximum.

This Hot Downcoiler of improved design supplements two others previously installed to serve the 80" wide Hot Strip Mill in the Abbey Works of The Steel Company of Wales Limited. Driven by a 300 h.p. motor it can coil hot band strip up to $\frac{1}{4}$" thick by 74" wide at speeds up to 2,000 feet per minute.

Ancillary features include pinch rolls with remotely controlled motorised gap adjustment; an easily removable carry-over roller table, required when the mill is rolling straight length plate, which can be lifted out in less than an hour to give access to wrapper rolls and mandrel; a new type downender with motorised lift to accommodate varying coil diameters. Closed circuit T.V. is provided as an operational aid in the control pulpit.

Builders of Capital Equipment
For the Metals Industries

DAVY-UNITED

SHEFFIELD | MIDDLESBROUGH | GLASGOW

224/D U.

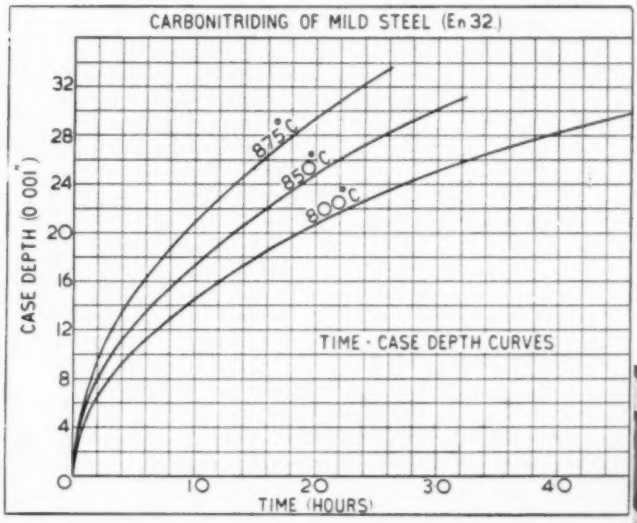
WILD BARFIELD CARBONITRIDING

... the best in every case

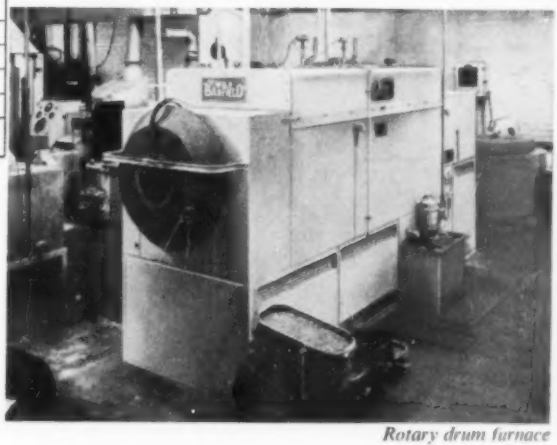
CONSIDER THESE POINTS:

- Clean working conditions
- Unskilled labour may be employed to carry out the process
- Post-cleaning operations reduced
- No storage space required for case hardening materials
- Simple system of atmosphere control

Shaker hearth furnace



- Atmosphere employed is raw Town's Gas and Ammonia
- No costly gas preparation plant required
- Batch or continuous equipment
- Consistent repetitive results



Rotary drum furnace

ELECTRIC WILD BARFIELD FURNACES

FOR ALL HEAT-TREATMENT PURPOSES

WILD-BARFIELD ELECTRIC FURNACES LIMITED

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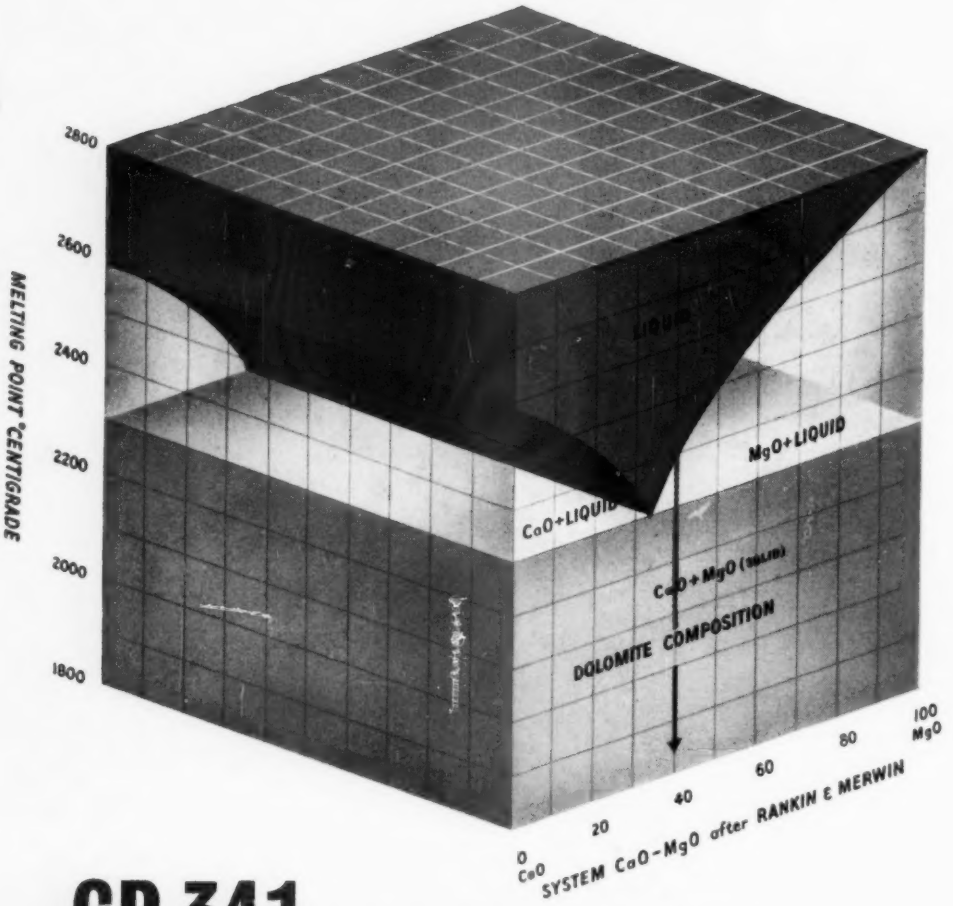
WB54

Important News

for the Basic Steel Industry



New GR 341 Dolomite Brick Process

Dolomite an indigenous raw material relatively low in cost, is widely distributed in Great Britain. Its high melting point fits it for use in many metallurgical processes. Dolomite is the backbone of the basic steel industry. General Refractories have developed a new process of making bricks from this unique raw material, and they offer the "341" Dolomite brick to the steel industry for use in a wide range of applications.

APPLICATIONS

Basic Bessemer Converters

Basic O.H. Furnace sub-hearths, bottoms and checkers

Electric furnace side-walls and bottoms

KAL-DO, L.D., ROTOR } *Oxygen-Steel Converters*

Active mixer sub-hearths and banks

GR Technical Service Department is available for consultation by users in the selection and application of these and other refractories.

GENERAL REFRACTORIES LTD.

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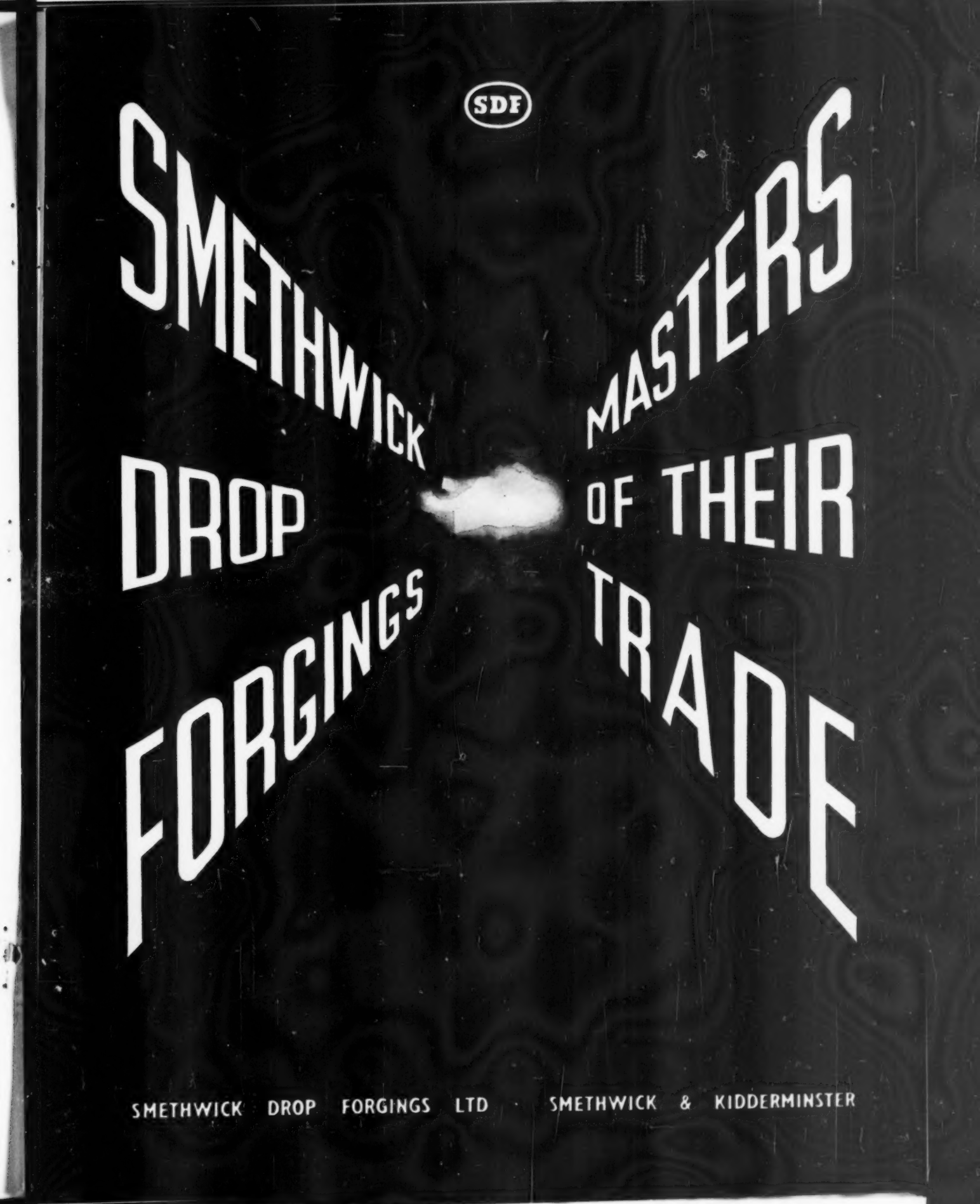
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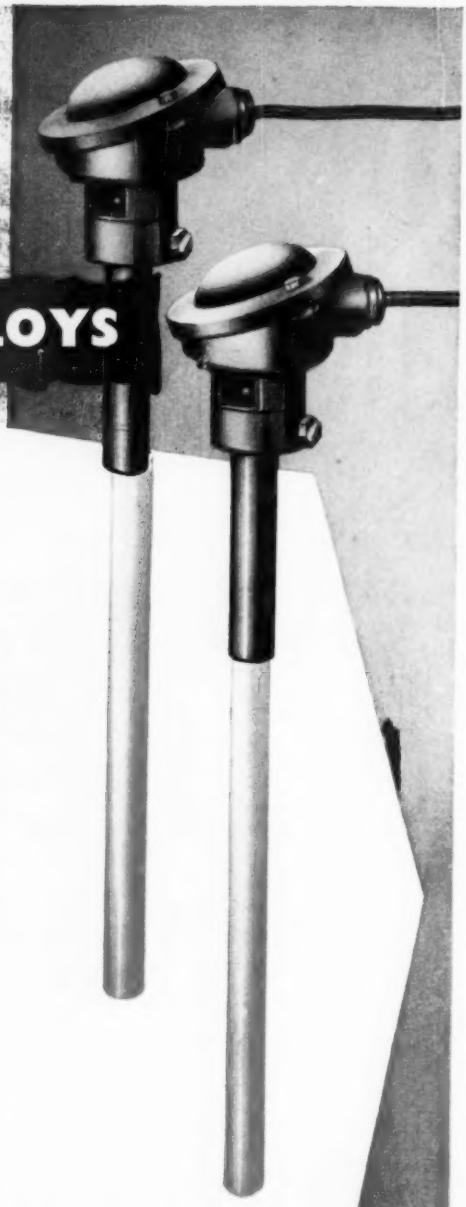
MASTERS OF THEIR TRADE
SMETHWICK DROP FORGINGS LTD · SMETHWICK & KIDDERMINSTER

High Temperature

THERMOCOUPLE ALLOYS



"Ni-Cr (plus) v/s Ni-Al (minus)"

Conforming to B.S. 1827:1952

The Thermo-electric properties of the Nickel-Chromium/ Nickel-Aluminium Alloys "Ni-Cr(Plus)" and "Ni-Al (Minus)", are in strict conformity with those stated in the American National Bureau of Standards Circular 561, and British Standard Institution Reference Tables for Thermocouples, B.S. 1827:1952.

For Compensating Cables and Extension Leads in Civil and Military Aircraft, "Ni-Cr(Plus)"/"Ni-Al(Minus)" Wires have Ministry of Supply (Air) type approval, for Cables manufactured to Specifications EL. 1705 and 1632.

LOW TEMPERATURE THERMOCOUPLE WIRES:—
CONSTANTAN v PURE IRON
CONSTANTAN v H.C. COPPER

We manufacture a special quality of Thermocouple iron and are able to supply matched wires in the Iron v Constantan combination to meet customers' varied Thermal-EMF requirements. Furthermore, and of infinitely greater importance, we are able to guarantee the reproducibility of those thermo-electric properties.

When ordering Compensating Leads from your usual supplier, for greater accuracy specify: "Thermocouple Wires made by A. C. Scott & Co. Ltd., preferred".

A. C. SCOTT & COMPANY LIMITED

TECHNICAL ALLOY MANUFACTURERS FOR OVER THIRTY YEARS

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Tel: WYThenshawe 5533/3 Grams: Cromaloy, Manchester

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GAS BLAST COMBINED FORGE AND BRAZING HEARTH

Complete with Motor Driven Positive Air Blower, two Gas Blast Blow Pipes and one Gas Blast Burner. Suitable for Tube bending up to 1 in. diameter.

Size of Hearth, 20 in. × 20 in. × 4 in.

Gas Consumption, 200 cu. ft. per hour maximum.

NATURAL DRAUGHT GAS FIRED SALT BATH SUITABLE FOR CYANIDE OR NEUTRAL SALTS

Suitable for temperatures up to 900° C.

Obtainable in the following sizes :
8 in. dia. × 8 in. deep, gas consumption 300 cu. ft./hr.
8 in. dia. × 10 in. deep, gas consumption 350 cu. ft./hr.
10 in. dia. × 12 in. deep, gas consumption 400 cu. ft./hr.

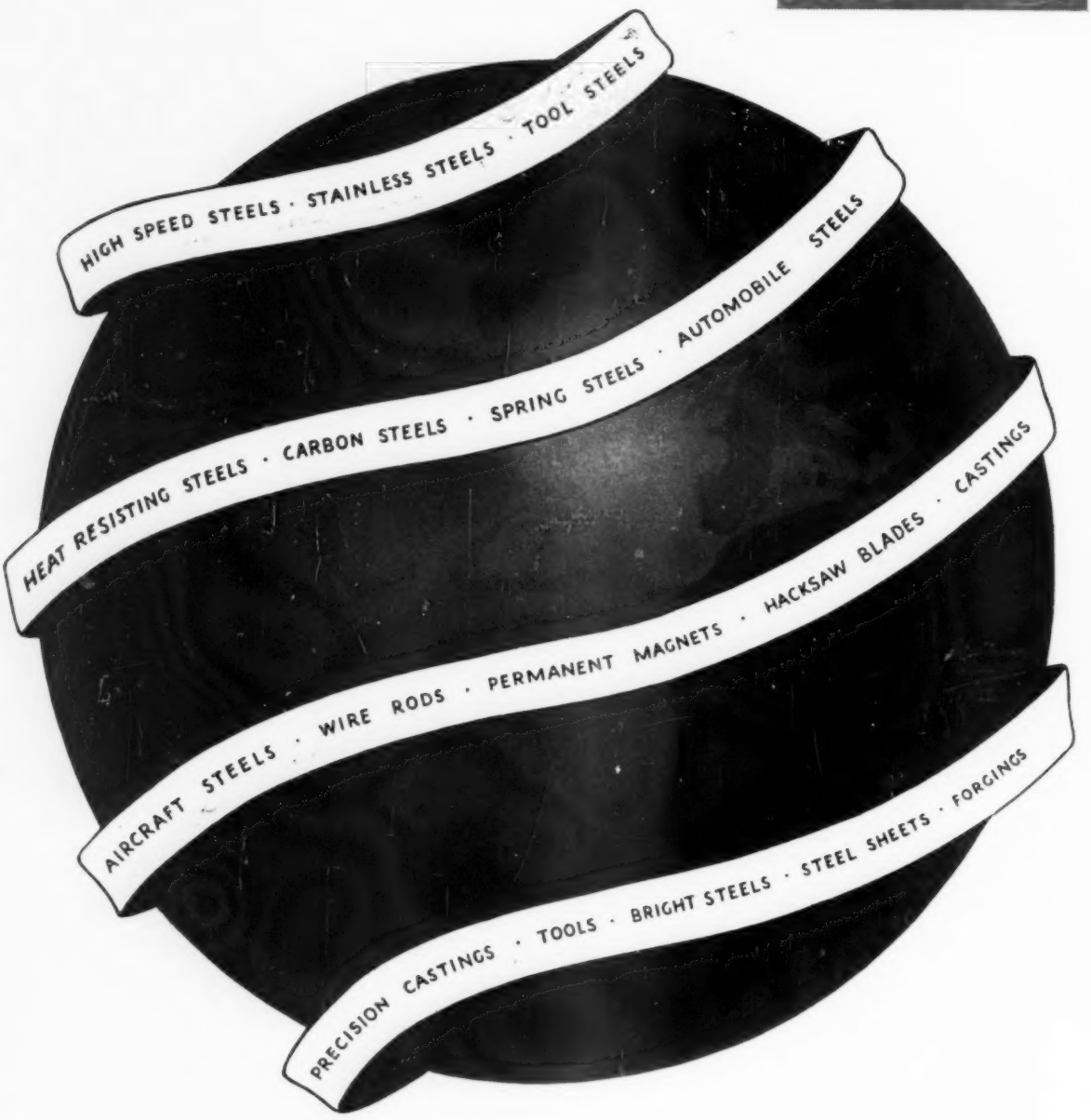
Time to heat up—1½ hours.

Manufactured by

KASENIT LTD

7, HOLYROOD STREET · BERMONDSEY · LONDON, S.E.1

EVERY PRODUCTION NEED IS FULFILLED BY DARWINS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PRECISION CASTINGS · TOOLS · BRIGHT STEELS · STEEL SHEETS · FORGINGS

All round the world, the steels and steel products of the Darwins Group are renowned for their exceptional quality and durability. Experience and service have placed Darwins in the front rank of quality steel production.

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SHEFFIELD ENGLAND

Serving the major industries throughout the world

THE DARWINS GROUP
D.100.

AMMONIA

From I.C.I. AMMONIA–

Nitrogen and Hydrogen for Industry

I.C.I. Ammonia provides industry with a cheap and reliable source of pure nitrogen and hydrogen. And I.C.I. gas generating plants are available to convert ammonia into a wide range of nitrogen hydrogen gas mixtures.

Anhydrous Ammonia with a guaranteed minimum purity of 99.98%, to meet more exacting requirements, is offered in bulk and in a wide range of cylinder sizes.

HYDROGEN

NITROGEN

Liquefied Ammonia *(Industrial Quality)*, a cheaper grade, is available in bulk and in two-ton containers for the larger consumer, and makes possible substantial economies in gas costs.

A bulk delivery of 10 tons of ammonia provides over 1¼ million cu. ft of nitrogen.

Full information on request.

IMPERIAL CHEMICAL INDUSTRIES LIMITED, LONDON, S.W.1.

ICI

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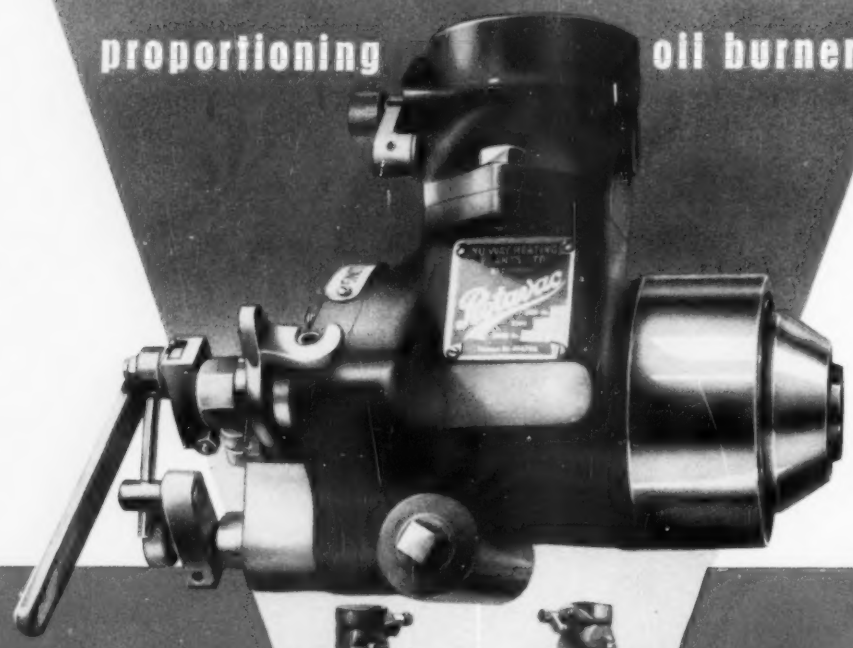
Nu-way
presents
ROTAVAC P.R.N. SERIES
proportioning oil burners



Advantages

1 ONE LEVER controls both oil and air, keeping the ratio constant from maximum to minimum firing rate. Easily and efficiently operated by unskilled labour.

2 RADIAL MOVEMENT allows burner to be easily controlled in groups on one furnace instantly and accurately by shaft or cable. Manual or automatic control.

3 QUICK-RELEASE inner assembly makes nozzle cleaning a simple operation. Patent wicket-swivel latch overcomes sticky fuel o.h.

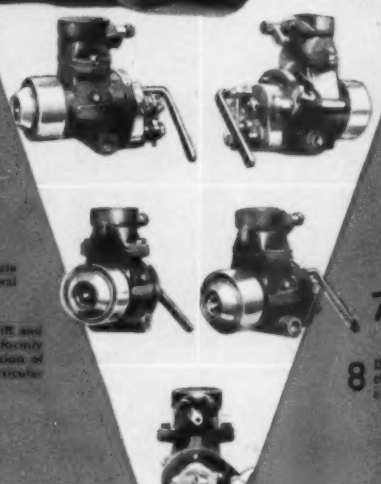
4 ANY FURNACE ATMOSPHERE selected at will and maintained throughout firing range with uniformity, high CO_2. Often gives reduced fuel consumption of 10–8%, when replacing ordinary burners in particular applications.

5 VARIABLE AIR/OIL VALVE COUPLING allows selection of the correct air/oil ratio while the burner is running. Any ratio once selected remains constant from high to low flame. For extra-low flame see below.

6 EXTRA-LOW FLAME SHIELD provides reduced air pressure to give a smaller stable low flame for special applications.

7 REGULATING SLEEVE allows adjustment of flame shape while the burner is in operation.

8 ISOLATOR VALVE shuts off air supply when servicing the burner. An intermediate setting gives reduced air pressure for quicker simpler lighting.



MODELS

PRN. 1 cap. 3½ imp. gals/hr.
PRN. 2 cap. 6 imp. gals/hr.
PRN. 3. (available shortly)
PRN. 4. cap. 30 imp. gals/hr

Particulars from

NU-WAY HEATING PLANTS LTD. (Box A338) DROITWICH

and at LONDON, MANCHESTER, NEWCASTLE, GLASGOW BELFAST, DUBLIN, BRISTOL.

STEIN BASIC *Refractories*

Stein Refractories have proved their dependability in service to industry since** 1887. **Constant research ensures continued leadership.

View of end wall of basic open hearth furnace showing excellent condition of Mag C after a campaign of 22 weeks. Target area in silica normally lasts only 2/3 weeks.

Stein Mag C is burned Magnesite-Chrome brick. Its most important physical characteristics are volume stability, high refractoriness under load, and reduced iron oxide expansion.

TECHNICAL DATA

Bulk density	1·67 ozs/in² (2·88 gms/cc)
Apparent Porosity	21%
Cold Crushing Strength	8,000 lb/in² (570 kgs/cm²)
After Contraction 2 hrs. 1760°C	–0·48%
Refractoriness—under-load 28 lb/in² (2 kgs/cm²)	5% deformation at 1720°C

APPLICATIONS

- Basic Open Hearth Steel Furnaces—Roof, port ends, uptakes, linings, checkers.
- Basic Electric Steel Furnaces—Upper side walls, roof; Copper Smelting Furnaces—Roofs and Linings.
- Copper Refining Furnaces—Roofs and linings; Basic Cupola—Melting Zone.

Use our advisory service based on 70 years experience in the refractory field—it can improve your furnace efficiency. For further information write, phone or call—

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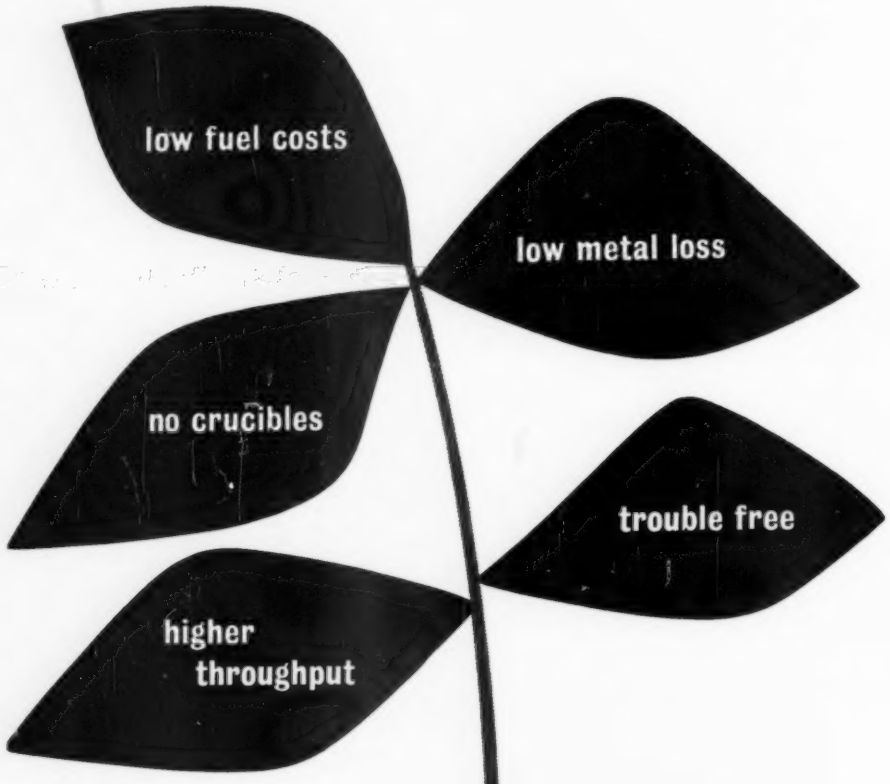

cultivate economy

Sklenar and Reverbale furnaces are ideal plants in any foundry—they cut fuel costs by half and eliminate crucibles. The Sklenar is a reverberatory, self-contained unit, melting lead, aluminium, bronze, brass or grey iron quicker and cheaper. Gas, coke or oil fired, capacities are from 50 lbs. to 10 tons. 200 lb. of die castings per hour can be produced from a Reverbale Junior Furnace using only a gallon of fuel oil.

We will gladly send you our book "Efficiency in Melting".

A Reverbale Junior furnace

A Sklenar furnace—photo by courtesy of Western Foundries, Southall, Mddx.

SKLENAR FURNACES LTD.

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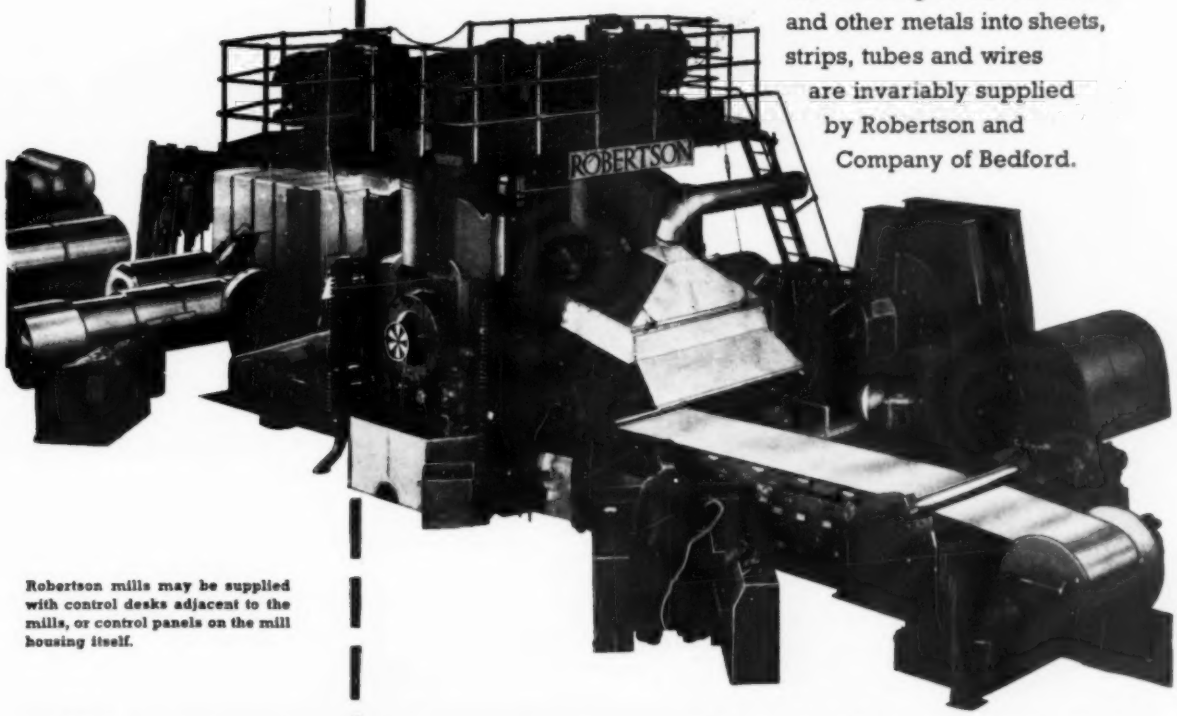
P.984

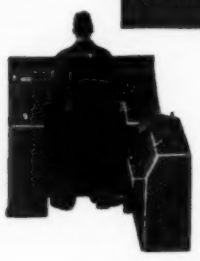
MAN AND MACHINES

Research and development, always keeping abreast and often ahead of the times, has been Robertson's policy since the days of their first machines designed in 1907 to help man increase production. For over 50 years, the high standard of design and quality finish of their products have kept the name 'Robertson' synonymous with the high class machines demanded by master craftsmen in metals. Today, the finest machines for reducing steel, aluminium and other metals into sheets, strips, tubes and wires are invariably supplied by Robertson and Company of Bedford.



Robertson mills may be supplied with control desks adjacent to the mills, or control panels on the mill housing itself.

High speed Aluminium Strip Finishing Mill



For thicknesses from : 0.25 in. (6 mm.) to under .012 in. (0.30 mm.)
Max. Width : 53 in. (1,300 mm.) Max. Speed : 1,000 ft. (300 m.) per min.
This Robertson Four-High Reversing Cold-Rolling Mill was recently supplied to the Société Industrielle de l'Aluminium, Duffel, Belgium, for finishing hot rolled aluminium and light alloy strip. It is the most efficient high speed mill of its kind yet installed.

W. H. A. ROBERTSON & CO. LTD., BEDFORD, ENGLAND

LICENSEES FOR THE BUILDING OF SENDZIMIR COLD REDUCTION MILLS & PLANETARY HOT MILLS, HALLDEN FLYING SHEAR MACHINES AND TORRINGTON WIRE FLATTENING AND EDGING MILLS W.T. 308

Direct constant & immediate readings accurate to ·00001"

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ELECTRONIC

GAUGING EQUIPMENT

A multi-purpose instrument, which can be used as very high precision standards room equipment, and yet is capable of meeting these same exacting conditions in production. It provides for very fast routine inspection and lends itself to multiple and continuous gauging, automatic sorting, remote control and inspection, and machine control.

For very fast routine or repetition inspection by non-technicians, a colour light signalling system can be incorporated to supplant the scale readings.

A demonstrator is always available for demonstrations on site.

Magna Gage and probe. Price £69-10-0. Immediate delivery.

The standard equipment for routine inspection

Magnification: 400 and 4000 approximately. *Ranges:* ·005–0–·005 in. Each division ·0001 in. ·0005–0–·0005 in. Each division ·00001 in. ·12–0–·12 mm. Each division ·005 mm. ·012–0–·012 mm. Each division ·0005 mm. *Accuracy:* ·0001 in. (·0025 mm.) on coarse ranges. ·00001 in. (·00025 mm.) on fine ranges. *Consistency of reading:* ±·000001 in. (±·000025 mm.) with standard probe. ±·000002 in. (±·00005 mm.) with extended probe. *Temperature coefficient of probe:* Zero shift lies within ±·0000005 in./deg. F. (±·00002 mm./deg. C.). *Operating pressure:* Varies from 1–2 oz. (28–56 gm.). *Zero drift of amplifier:* After 2 minutes' warm-up, ·00002 in. (·0005 mm.). After 10 minutes' warm-up, ·00001 in. (·00025 mm.). *Zero stability with mains change:* Undetectable for voltage changes of ±15% and frequency changes 40–60 c/s. *Reading stability with mains change:* No change for frequency 40–60 c/s. ±1% of reading for ±15% voltage change. *Electrical outputs:* Current: ±0·5 mA. full-scale on any range. Maximum load 4700 ohms. Voltage: ±2·5 volts (approximately) full-scale on any range. Output resistance 4700 ohms. *Mains supply:* 100–115, 200–250 volts, single-phase, 40–60 c/s. *Power consumption:* 20 watts. *Probe dimensions and weight:* Diameter: ·875 ±·0005 in. (22·22 ±·01 mm.). Overall length: 3·5 in. (9 cm.). Weight with cable and plug: 4 oz. (112 gm.). *Amplifier dimensions and weight:* Size: 8×8×8 in. (20×20×20 cm.) approximately. Weight: 8¾ lb. (4 Kg.).

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We specialise in the design and construction of :-

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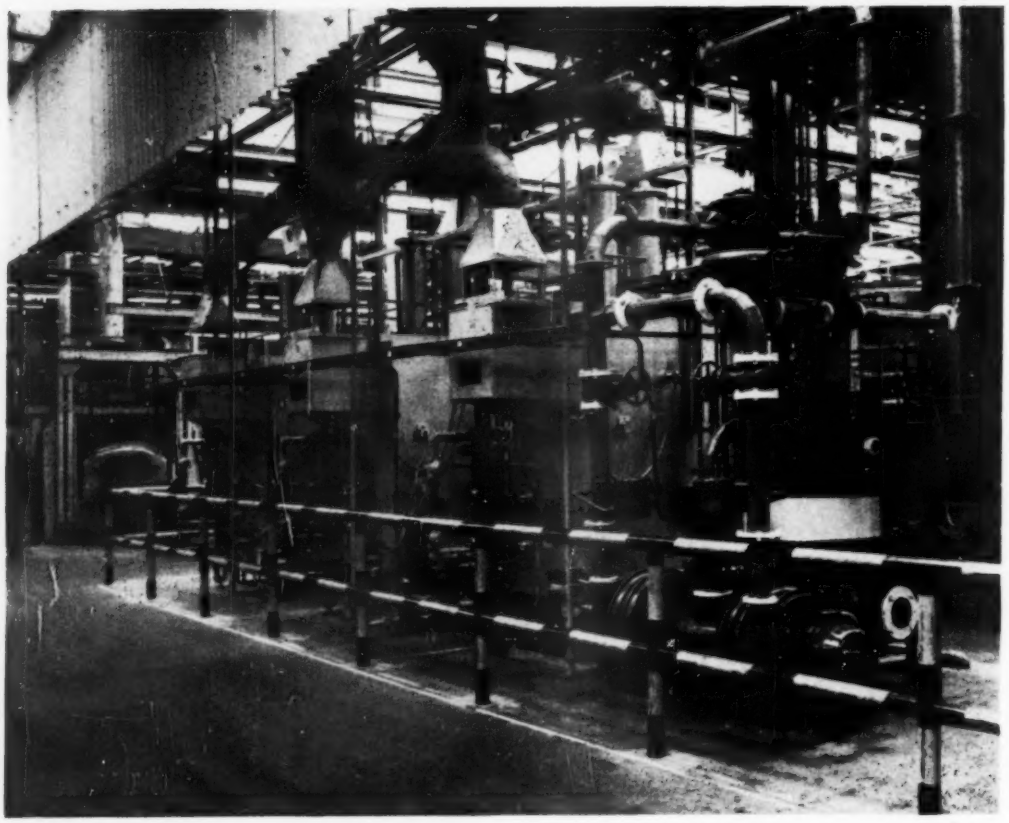
THE ECONOMY OF QUALITY



ENDOTHERMIC GAS GENERATING UNITS AT VAUXHALL MOTORS LTD.

THE VAUXHALL 'VICTOR'

In accordance with their usual policy that only the best is good enough Vauxhall choose Gas Generating Units backed by 25 years' experience for their Luton and Dunstable extensions.

The endothermic gas requirements at Luton are supplied from five " RX " units and three similar units are installed at Dunstable.

" RX " Units installed or on order have a total gas capacity of over 52,000 cubic feet per hour.

These units offer the most in all-round advantages—in uniform quality gas of relatively high carbon potential easily controlled.

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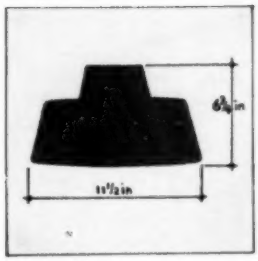
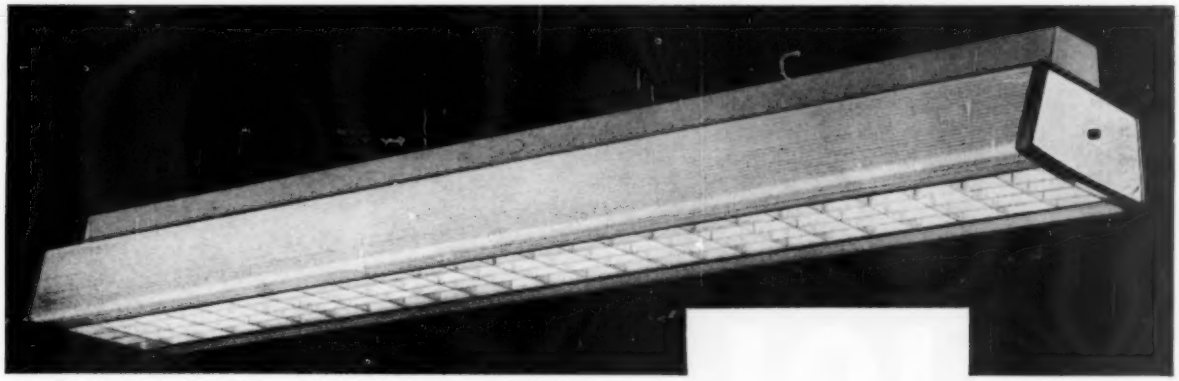
ASSOCIATED WITH SURFACE COMBUSTION CORPORATION · TOLEDO — U.S.A.



one of many decorative designs

The brilliantly successful G.E.C. 101 range of fluorescent fittings offers a wide choice of designs for every lighting requirement — in executive offices, showrooms, shops and stores, as well as factory areas. They are made for 1½ to 8 ft. single or twin Osram guaranteed tubes, and all employ the famous G.E.C. Basic Channel with its proven advantages of versatility and economy in installation and maintenance.

The fitting illustrated, F41130/1, has sides of reeded 030 'Perspex' and a white louvre. The ends are polished brass with an inset white panel. The top and bottom openings of the 'Perspex' are similar and the enclosure can be used as shown, or inverted.



range

fluorescent lighting fittings

G.E.C.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

BRIGHT STEEL
ROUNDS · HEXAGONS ·
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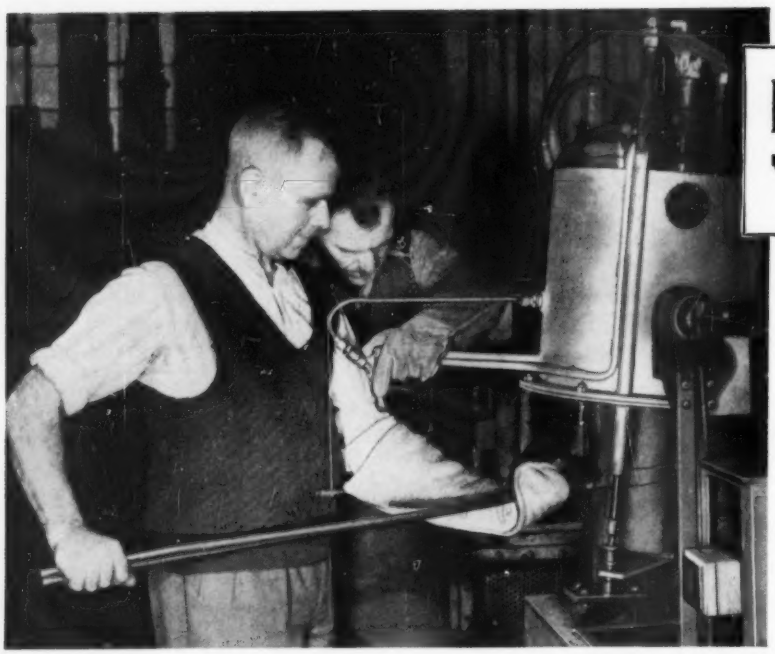

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USE R.M.C. CRUCIBLES

Where purity of castings is required it pays to specify Refractory Mouldings & Castings crucibles. Whether you are melting by arc or high frequency, they provide good resistance to thermal shock, and resist erosion. These are a few of the reasons why Rolls-Royce and other leading Precision Casters depend upon R.M.C. refractories. *Deliveries are good. Why not write for further information?*

- *Made to individual requirements.*
- *Rapid delivery.* • *Close tolerances.*
- *Good resistance to thermal shock.*
- *Resist erosion.* • *Fewer inclusions.*
- *For temperatures up to 2000° C.*

WE ALSO MAKE SPECIAL REFRACTORIES TO CLOSE TOLERANCES FOR A WIDE VARIETY OF APPLICATIONS FOR RESEARCH AND DEVELOPMENT WORK.

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REFRACTORY MOULDINGS & CASTINGS LIMITED
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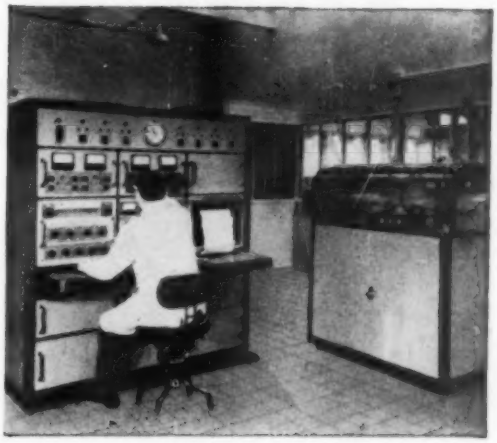
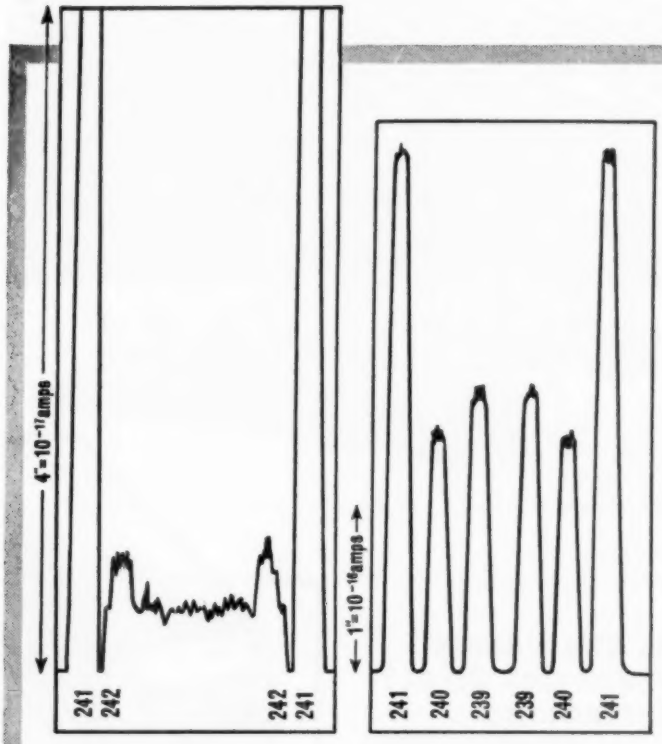
The Metropolitan-Vickers Range of Scientific Equipments includes apparatus for the investigation of metallurgical, chemical and biological problems in research, production or processing. These equipments cover a wide selection of specialised scientific apparatus.

to Scientific Ends



MASS SPECTROMETER TYPE MS5 *An instrument specially designed for the measurement of isotope ratios of inorganic solids by the surface ionisation technique.*



ANALYSIS OF PLUTONIUM

$\frac{m}{e}$	239	240	241	242
% ABUNDANCE	27·20	23·10	49·60	0·072
STANDARD DEVIATION	0·25	0·30	—	0·007

Tabulated results and traces from sample of approximately 10^{-8} grams of plutonium nitrate, using the triple filament technique and the multiplier detector. The standard deviation quoted is taken on 10 measurements.

METROPOLITAN-VICKERS
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N/R805

LIQUEFIED PETROLEUM GAS PLANT

by **HOLMES**

The Holmes L.P Gas Plant illustrated above supplies propane vapour to furnaces (installed by our Associate Company—British Furnaces Ltd) used for carburising vehicle parts at the Luton Works of Messrs. Vauxhall Motors Ltd. Consistent quality of sulphur free gas facilitates the rigid control necessary for this process.

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BUTANE/AIR FOR TOWNS GAS SUPPLY
PRODUCTION OF CONTROLLED ATMOSPHERES
SPACE HEATING · GAS CARBURISING
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W. C. HOLMES & CO. LTD
Gas Cleaning Division

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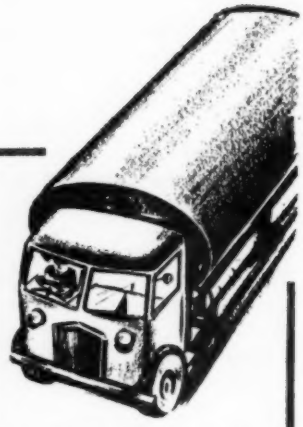
Technical Associates *Woodall-Duckham (Australasia) Pty. Ltd., 340 Spencer Street, Melbourne C.1*

C9390



Shell-Mex and B.P Gases Ltd., are suppliers of Liquefied Petroleum Gases. Commercial butane and propane are gases of high purity, consistent quality, low sulphur content and high calorific value. Bulk deliveries can be made by Shell-Mex and B.P. Gases Ltd. to all parts of Great Britain with their large fleet of tankers.

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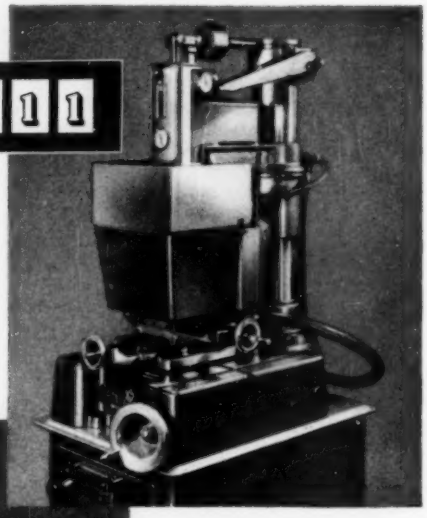
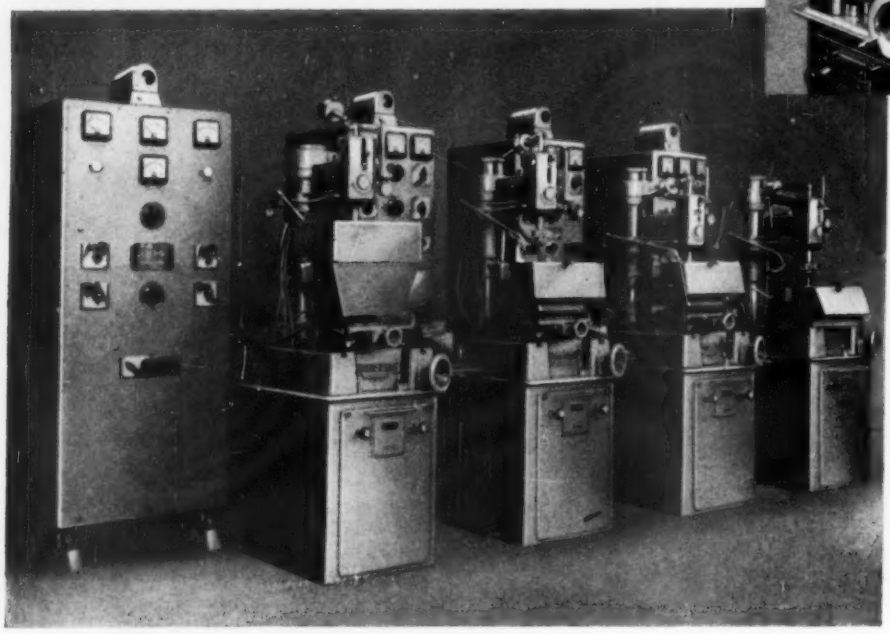
SPARCATRON Mk. III

6.5kW

The greatest advance since SPARCATRON established spark erosion machining on a commercial basis





Up to four spark-heads can be operated from one control cabinet. The current is automatically cut off when the electrode has penetrated the workpiece to a predetermined depth allowing one operator to supervise a number of heads.

CAPABLE of operating three to eight times as fast as the Mark II model, depending on the type of material and finish required, the latest SPARCATRON spark erosion machine, Mark III, has exceptional accuracy and increased capacity. The new design also features ease of access for loading the table and setting the servo-head and the facility for quick and accurate alignment of the electrode. SPARCATRON affords the best means of "cutting" intricate shapes, profiles, forms, or impressions in both hard and soft current-conducting materials.

SPARCATRON

Pioneered and established in the toolmaking industry for spark-machining and reconditioning press tools and dies and wire drawing and extrusion dies in cemented carbides and hardened steels. There are extensive applications for "cutting", reconditioning or altering flat and tangential form tools and similar components.

SP5

Manufactured by Impregnated Diamond Products Ltd.

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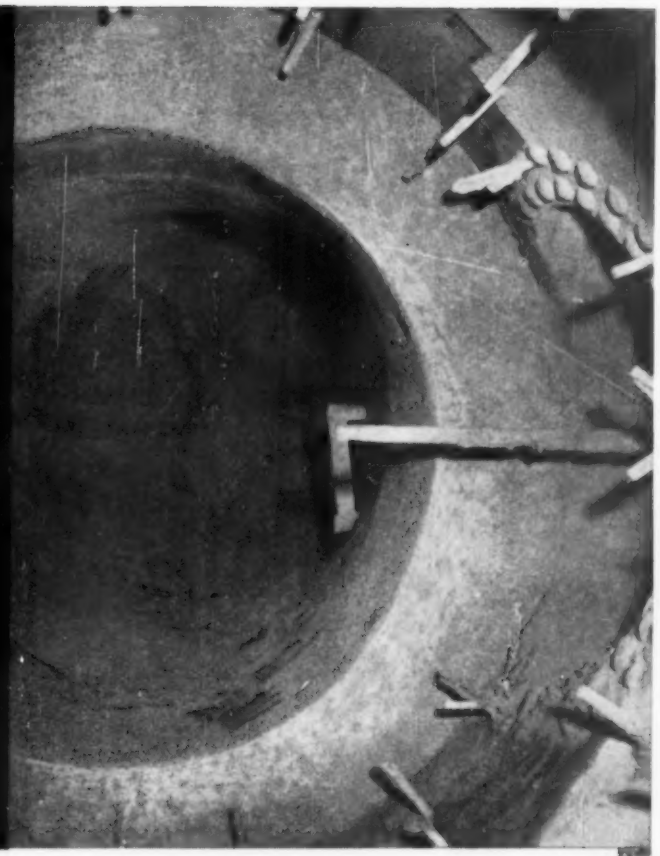
Tri-Mor Plastics and Castables make installation Easier Quicker and Cheaper



Bustle main of Queen Victoria Blast Furnace showing 'gunned' lining in Tri-Mor Dense 'Guncrete'. (Inside diameter of shell 5 feet. Thickness of 'Guncrete' lining 9 inches).
Photograph by courtesy of the Appleby-Frodingham Steel Co. (Branch of the United Steel Companies Ltd.).

TRI-MOR GRADES

TRI-MOR *Standard Castable*

A medium texture refractory having negligible shrinkage up to 1,350° C. Suitable for casting special shapes or for monolithic structures. Limiting service temperature 1,350° C.

TRI-MOR *High Strength Castable*

A similar refractory to Tri-Mor Standard Castable, but specially developed to have very high mechanical strength over the lower temperature range. Maximum service temperature 1,250° C.

TRI-MOR *High Temperature Castable*

Suitable for face temperatures up to 1,600° C; has an extremely high resistance to thermal shock; used for cast in situ monolithic structures and for pre-cast refractory shapes; can be applied with a cement gun.

TRI-MOR *High Temperature Mouldable*

A plastic refractory for use up to 1,650° C: low shrinkage and a high resistance to spalling. Supplied mixed to the correct consistency for installation.

TRI-MOR *Dense "Guncrete"*

A hydraulic setting refractory with a maximum service temperature of 1,300° C. It has a high resistance to abrasion. Designed for application by cement gun, but can be trowelled.

TRI-MOR *Insulating Castable*

An insulating castable for maximum service temperatures of 1,200° C; low thermal conductivity is its main feature.

TRI-MOR *Insulating "Guncrete"*

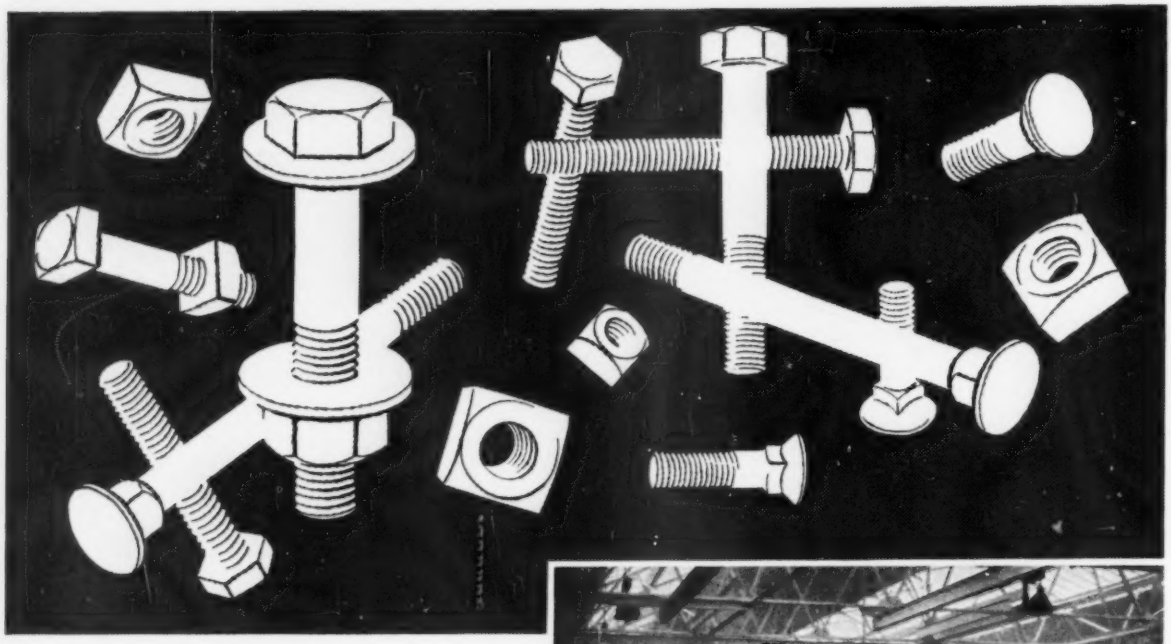
Similar to Tri-Mor Insulating Castable but for application by cement gun.

Full details of each grade are available on request.

MORGAN Refractories Ltd

For further information write to: MORGAN REFRACTORIES LTD NESTON, WIRRAL, CHESHIRE. TEL: NESTON 1406 NE 143

GKN AND G.W.B.



Two sets of initials, both of which stand for reliability. Millions of nuts, bolts, rivets and fasteners of all types leave the Darlaston (Staffs.) works of Guest, Keen & Nettlefolds (Midlands) Limited every week. Accurately made from the best quality materials, heat-treatment plays an important part in ensuring that they conform to the highest specifications.

Among the latest equipment installed by G.W.B. Furnaces Limited are three completely continuous lines of Hardening and Tempering furnaces. Each line comprises: 30 cwts. Loading hopper—De-greaser—Hardening furnace—Continuous quench extractor—Loading hopper—De-greaser—Tempering furnace—Continuous quench extractor. The Tempering units can also be used independently as Hardening furnaces if required. Each furnace has an output of 5/6 cwts. per hour, and the whole installation is served by two men only, one to supervise the general operation and one fork truck driver who, among his other general factory duties, loads the hoppers and conveys the full bins of heat-treated components to the Packing Dept.

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GWB217

B.E.R.L Specialised Lifting Tackle

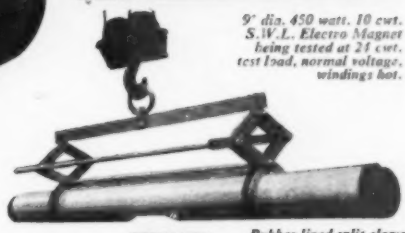
Type NRSA Plate Lifting Sling with common lifting ring with self aligning swivelling clamps. Range 1 to 10 tons.

Vertical cylindrical specified diameter lifting device.

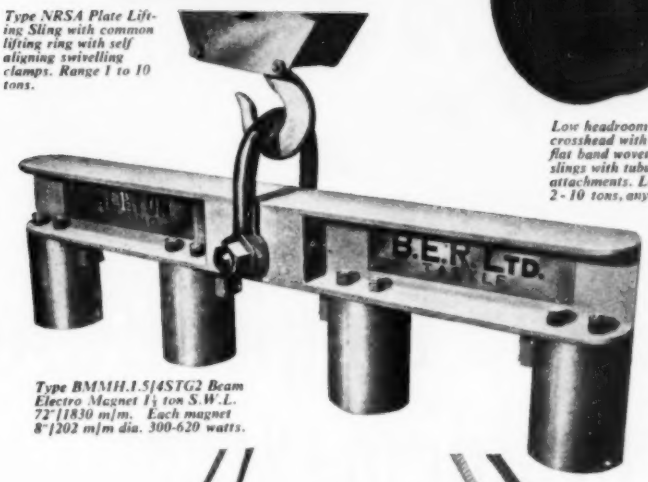
Horizontal cylindrical specified diameter lifting device, also supplied with special clamp faces for handling ground diameters.

9" dia. 450 watt. 10 cwt. S.W.L. Electro Magnet being tested at 24 cwt. test load, normal voltage, windings hot.

Low headroom all steel crosshead with pair of flat band woven wire slings with tubular end attachments. Load range 2 - 10 tons, any diameter.

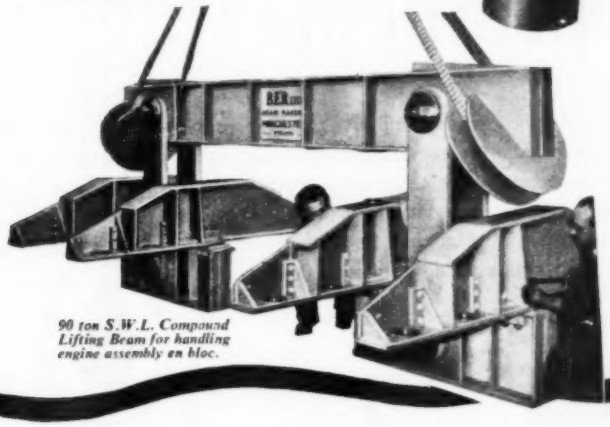


Rubber lined split clamp lifting device for hot semi-plastic loads.



Type BMMH.1.5/4STG2 Beam Electro Magnet 1½ ton S.W.L. 72"/1830 m/m. Each magnet 8"/202 m/m dia. 300-620 watts.

Ingot lifting device for lead or copper etc., to any size and rating required.



90 ton S.W.L. Compound Lifting Beam for handling engine assembly en bloc.

The BERL service is offered to all users of lifting tackle and illustrated above are some of the lifting devices from our extensive range. When dealing with your load raising problems remember BERL hold the answers.

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dm BER. 69

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A new Furnace with
360° Radiant Heat Element
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Diameter of Working Tube 1.092″

The Silit Tube Furnace Type ST.40/3 is a laboratory furnace suitable for tests and heat treatment at high temperatures. This Furnace is of compact design with instrumentation and control equipment housed in the Furnace bench mounting stand.

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Smee's S.04

Picture of a man . . .

. . . with all the answers on insulating bricks

He is finding that the use of insulating bricks for more effective heat insulation has been a subject well worth looking into. Reading further he'll see that Newalls make a range of insulation bricks under the trade names "Nonpareil" and "Newparex" which are designed to cover heat insulation requirements up to 2012°F (1100°C). But why not read the catalogue yourself? Like the man in the advertisement, you'll find factual answers to all your queries.

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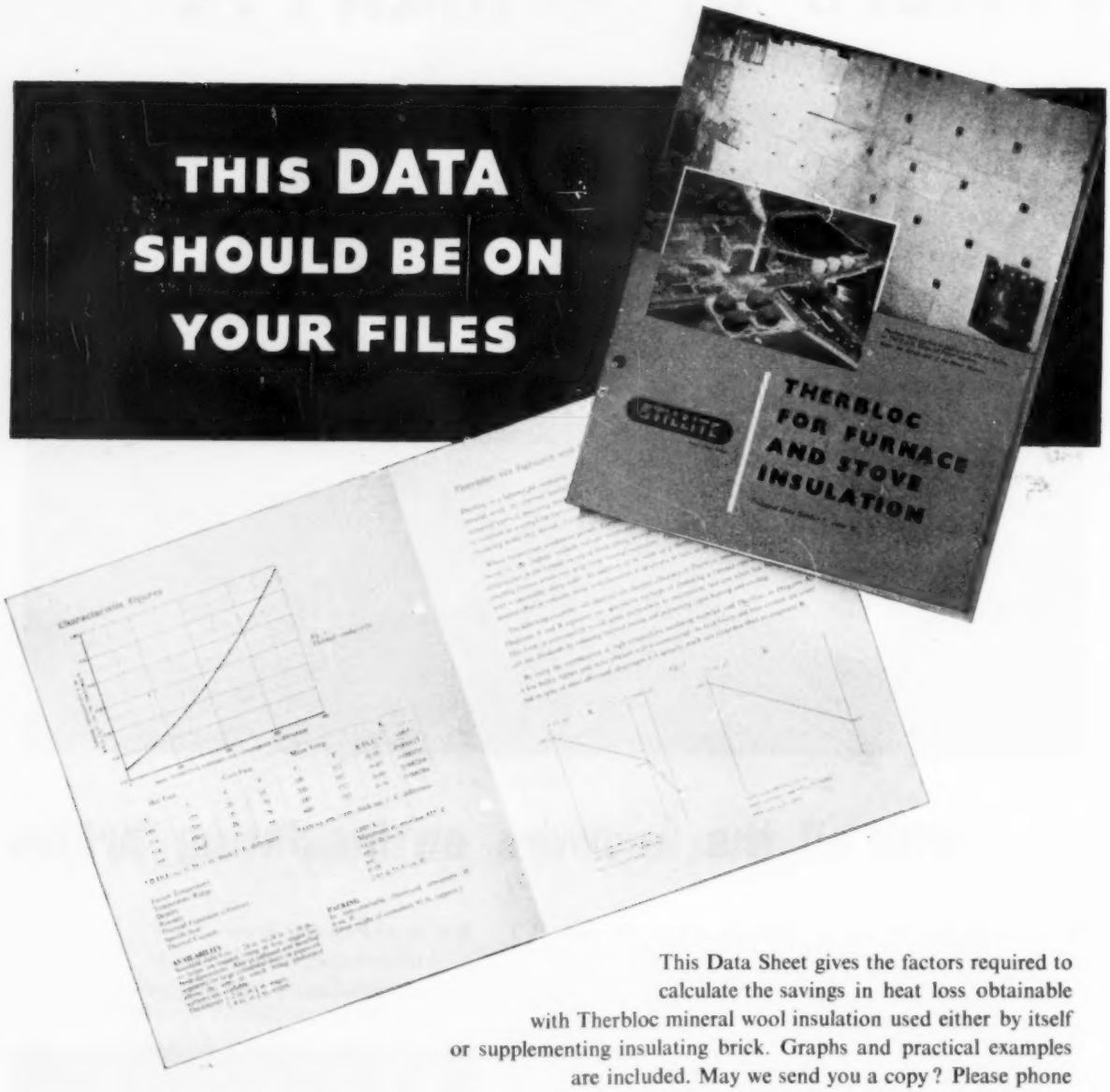
THIS DATA SHOULD BE ON YOUR FILES



This Data Sheet gives the factors required to calculate the savings in heat loss obtainable with Therbloc mineral wool insulation used either by itself or supplementing insulating brick. Graphs and practical examples are included. May we send you a copy? Please phone Whitehall 0922-6 or the coupon is for your convenience.

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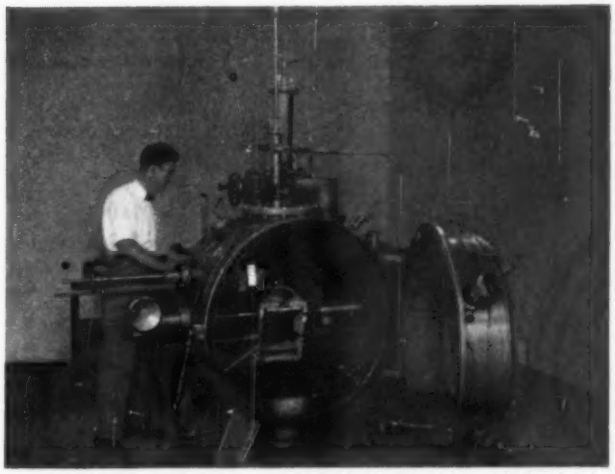
Both arc and induction furnaces are available, the former with consumable or non-consumable electrodes, cold mould or skull type. Induction heated equipments include the N R C patented semi-continuous vacuum melting furnaces.



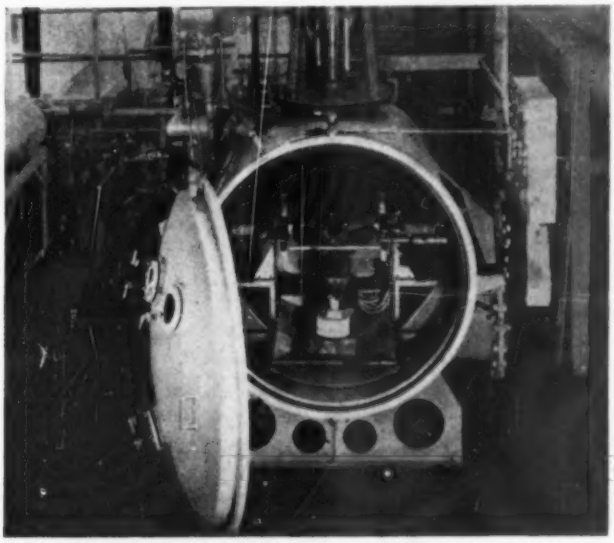
Model 2555 Vacuum Induction Furnace with melting capacity of 50 pounds of steel. Other standard furnaces have capacities of 12 to 3,000 pounds.

INDUCTION HEATED FURNACES FOR . . .

Melting, Alloying, and Purifying; Centrifugal, Ingot, Shape, and Investment Casting; Sintering, Brazing, Degassing and Heat-Treating.

ARC FURNACES FOR . . .

Melting and alloying high temperature or reactive metals such as niobium, tantalum, cobalt, zirconium and titanium.



Model 2705 Non-Consumable Arc Skull Furnace with a capacity of 50 pounds of titanium. Other standard vacuum arc furnaces have capacities of 8 to 10,000 pounds of titanium.

OTHER VACUUM EQUIPMENTS

- **Vacuum Fusion Gas Analyser**
- **Hydrogen Analyser**
- **Resistance Furnaces**
- **High Vacuum Diffusion Pumps**

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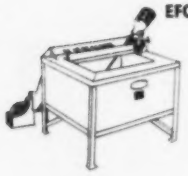

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for austempering and martempering up to 500°C.
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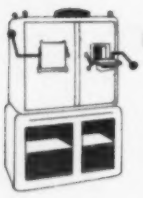

HIGH SPEED STEEL FURNACE—TWIN CHAMBER

Preheating up to 1000°C. and hardening up to 1350°C. without decarburisation.
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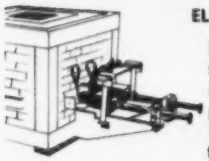
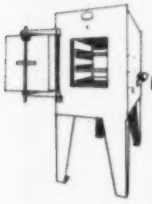
EFCO-UPTON CONTINUING GRAPHITE ELECTRODE SALT BATH



Hardening high speed steels, aluminium brazing and all processes up to 1300°C. with bath free from metallic oxides.
Publication R.27.



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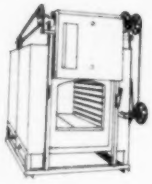
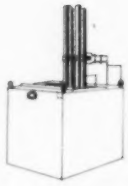


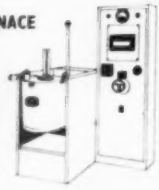
Box carburising and general treatment to 1150°C.
Publication R.3.

EFCO ELECTRIC SALT BATHS



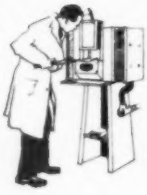
Cyanide hardening, carburising, neutral treatment to 1000°C.
Publication R.1.

EFCO SALT BATH FURNACE MIDGET TYPE



with interchangeable pots for processes from 600 to 1350°C. for small outputs.
Publication R.16.

EFCO SENTRY FURNACE



Diamond Block method of atmosphere control for high speed steel hardening up to 1350°C. Vertical or horizontal.
Publication R.6.

EFCO VERTICAL MUFFLE TYPE FURNACES

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Spec. Sheet 1729.

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Today aluminium is more plentiful, but the future will see a further expansion in demand. The improved supply will encourage new users to employ the metal for new applications. The Aluminium Limited Group has geared itself to meet this increasing demand.

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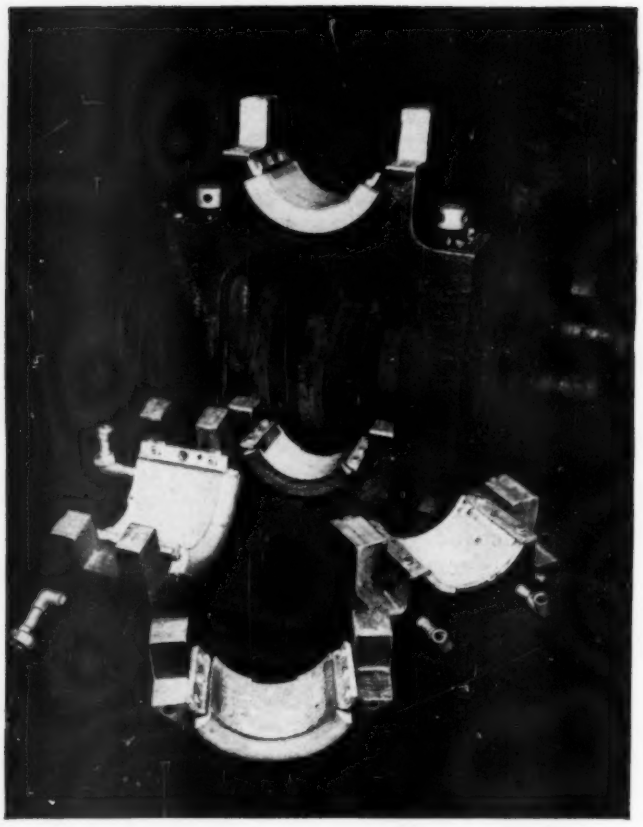

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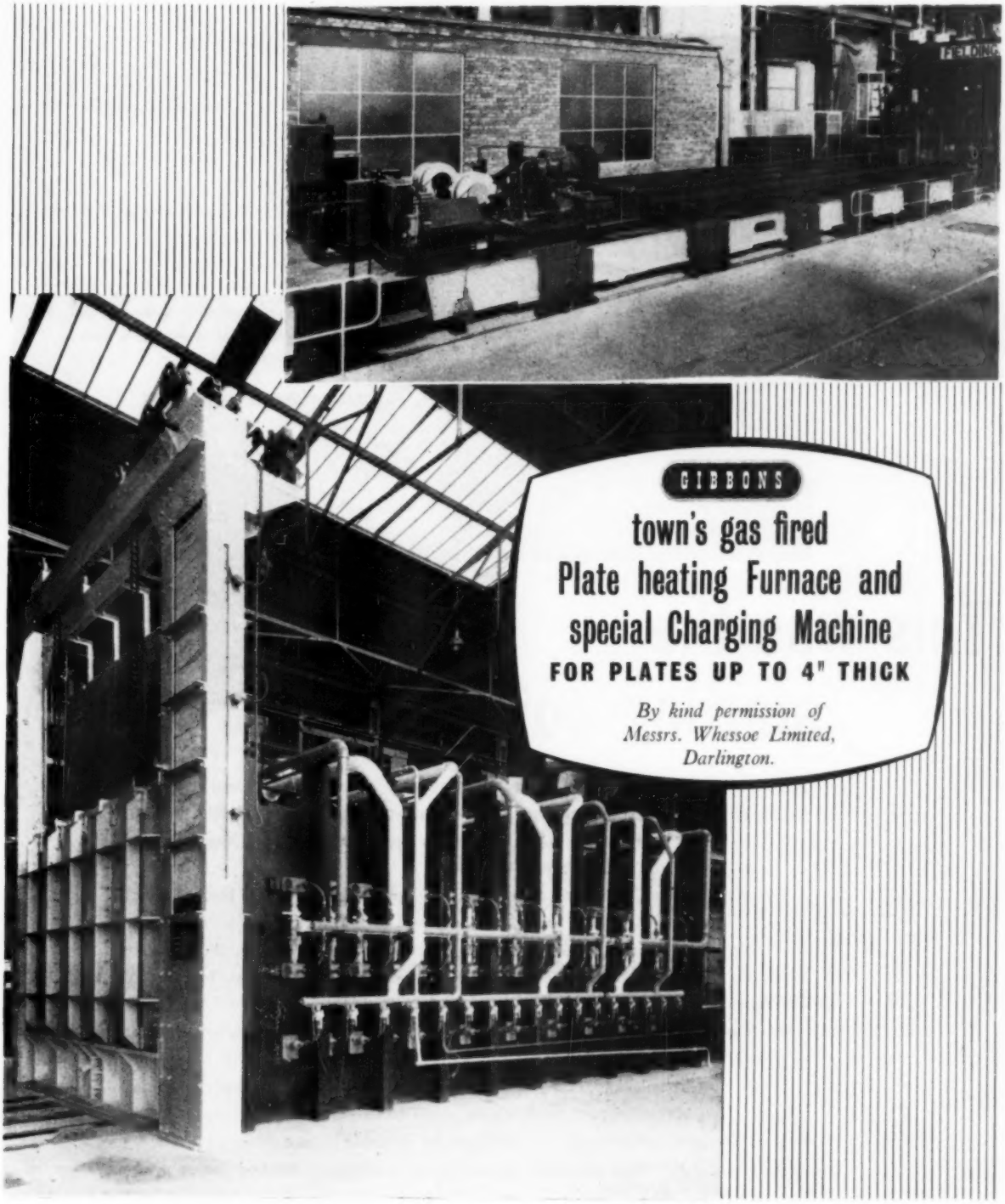

GIBBONS

town's gas fired Plate heating Furnace and special Charging Machine

FOR PLATES UP TO 4" THICK

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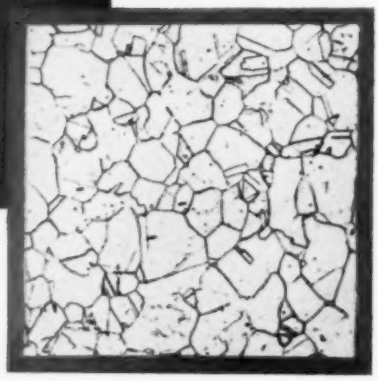

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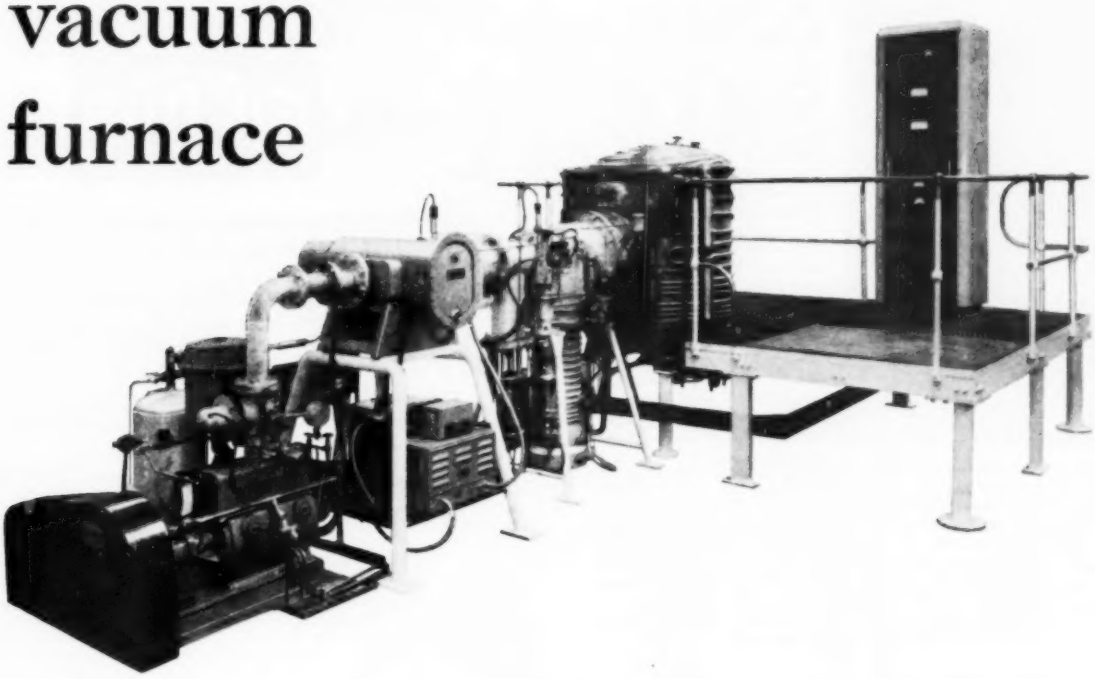

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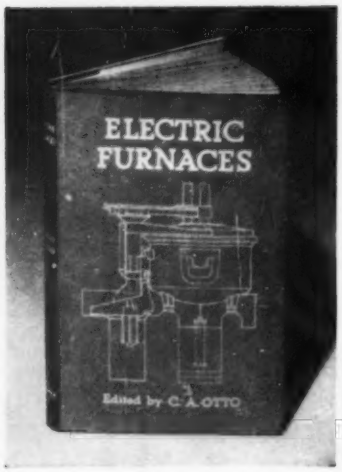

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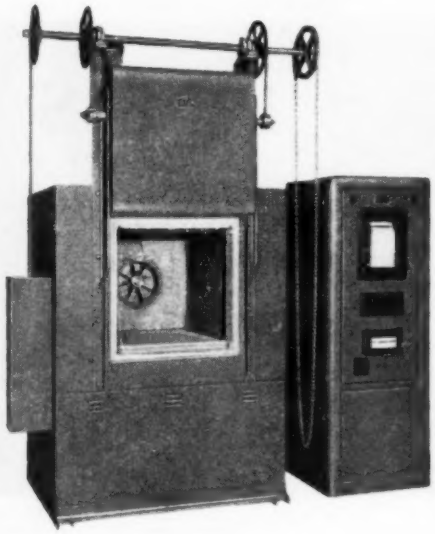

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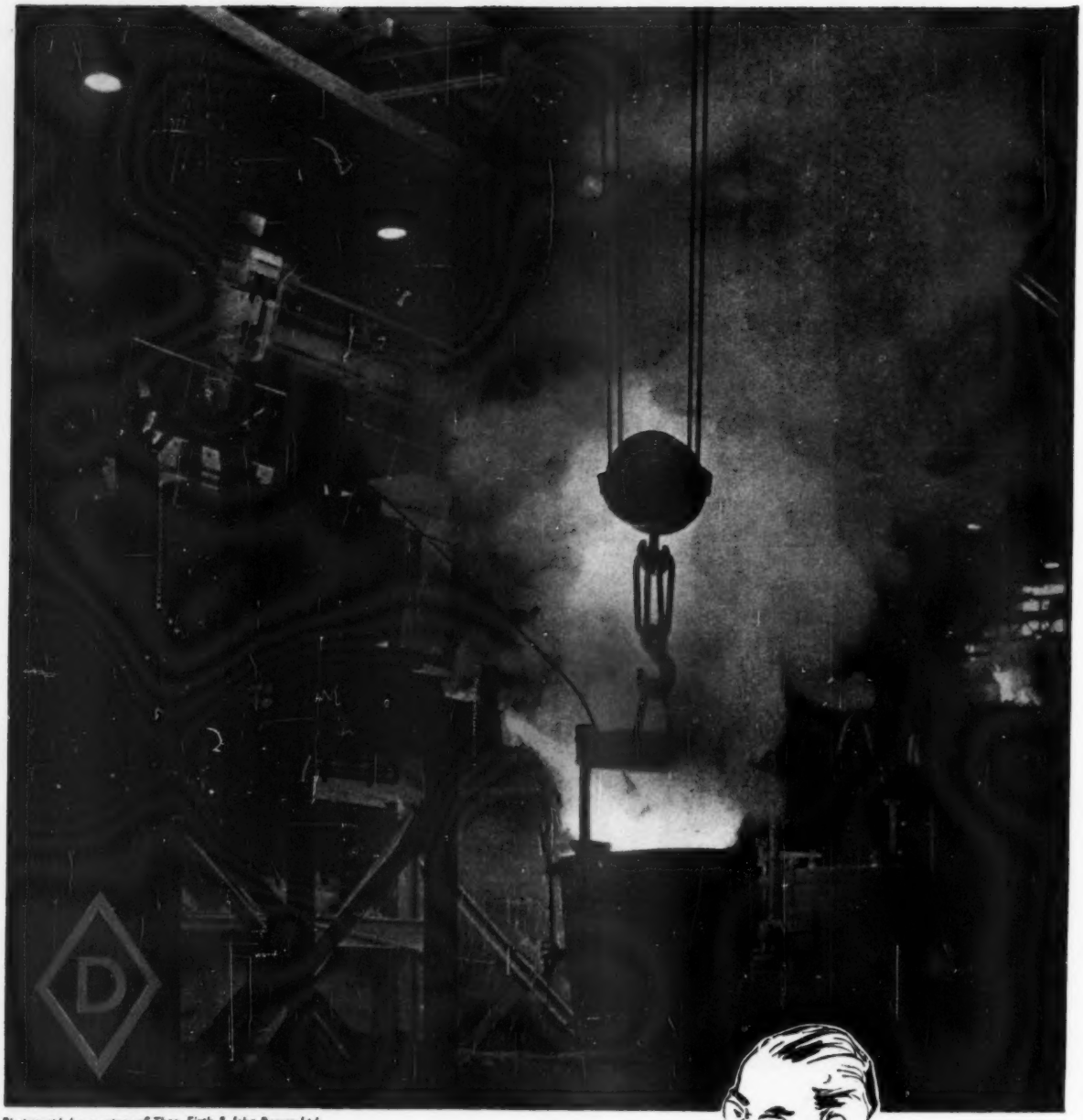

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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR JANUARY, 1959 Vol. 59 No. 351

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd., 31, King Street West, Manchester, 3.
Telephone : BLAckfriars 2084.

London Office :
158, Temple Chambers, Temple Avenue, E.C.4.
FLEet Street 8914.

CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages : photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—30/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

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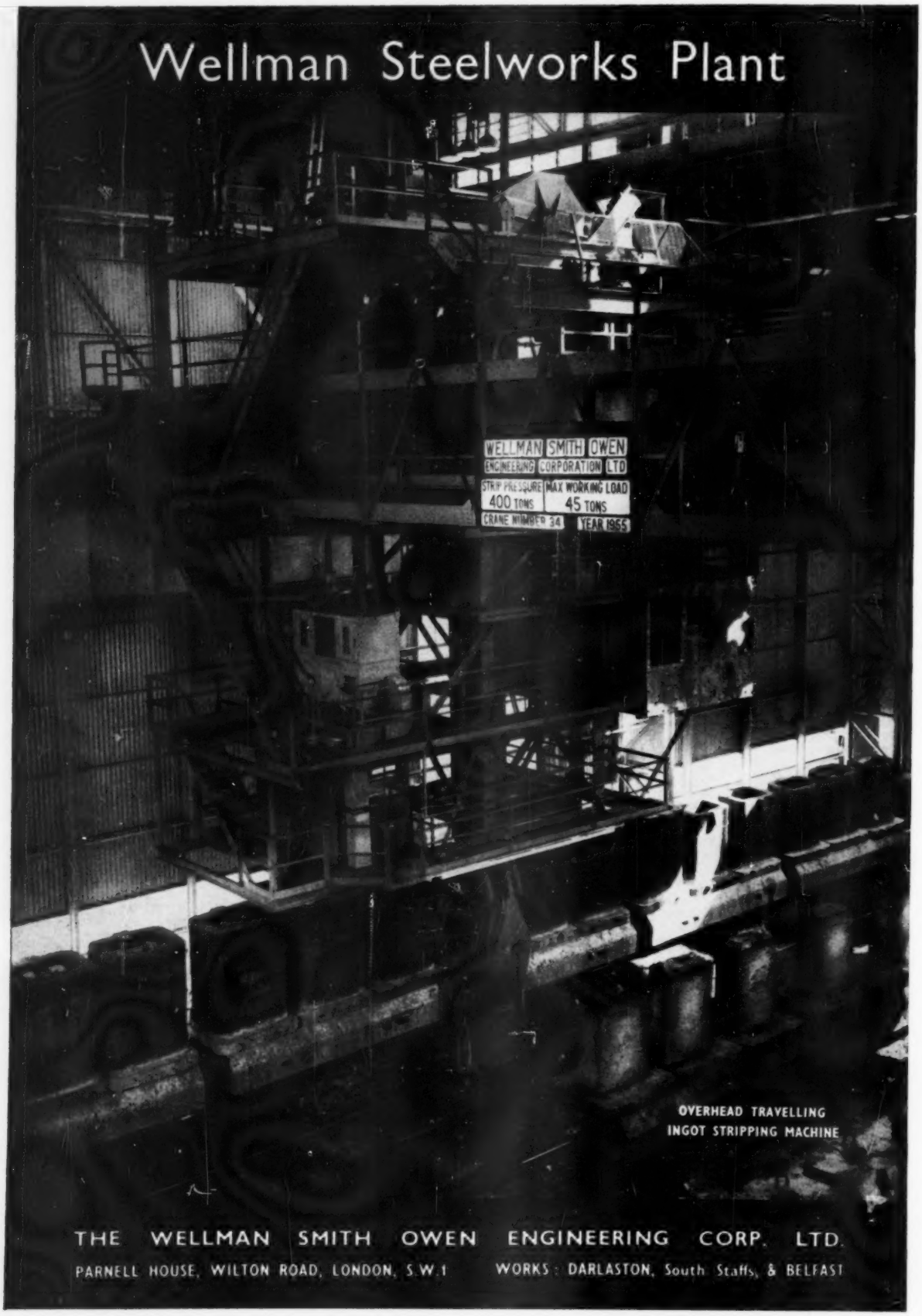

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JANUARY, 1959 Vol. LIX. No. 351

Steel Outlook

WE have become so accustomed to reading at this time of the year that steel output has increased yet again, as compared with the preceding year, that it comes as something of a shock when the trend is reversed, even though it has been obvious for months that this would be the case. Although the final figures are not yet available, it is likely that steel production in 1958, at 19·6 million tons, will be some 2·1 million tons less than in 1957. At the same time, the available steel producing capacity has been substantially greater—about 23·5 million tons.

The general picture is one of progressive decline in the demand for steel through the year, ranging from 1% below 1957 in the first quarter to nearly 20% in the fourth. Over the whole year the estimated fall in demand of 2·4 million tons (as compared with the 2·1 million tons fall in production) may be divided into three parts: 1·75 million tons due to contraction of home sales; 500,000 tons to the fall in direct exports; and 150,000 tons to lower indirect exports. On the production side there was a corresponding decline; ranging from 1% below 1957 in the first quarter to 18% down in the last quarter. This state of affairs was, of course, reflected in the raw materials position: the home production of iron ore and arrivals of imported ore in the first nine months of 1958 were both 17% lower than in the corresponding period of 1957, and coal consumption in the same period, including the coal equivalent of purchased coke, was some 2·5 million tons down. The greatest change, however, has been in the scrap position: since September, Britain has been a net exporter of iron and steel scrap. At the same time, the import of pig iron has virtually ceased.

Home consumption, i.e. the amount of steel used by the engineering and other industries, fell by a smaller amount than home demand, the difference being due to the running down of consumers' stocks. This process was accelerated by the general reduction in steel prices in March last, and in the third quarter of 1958 home consumption was 7% below a year ago whilst home demand was 16% less: the last quarter is likely to show an even greater difference.

As mentioned earlier, the capacity of the industry increased during the year, and in spite of the closure of some older plants, such as hand sheet and tinplate mills and the associated melting shops, the increase amounted to a million tons. With the increase in capacity and reduction in demand, the industry's plant is now seriously under-employed. Whereas, in the first half of 1957, British steelmaking facilities were working at 98% of capacity, the second half of the year saw a fall to 95%. Throughout 1958 there has been a progressive deterioration from 93% in the first quarter to an expected figure of 75% in the fourth.

So much for 1958, what of 1959? It is expected that steelmaking capacity will increase by about a million tons during the year, but most of this will come in at the wide strip mills, where the need is greatest, and this should obviate the need for sheet imports. The deteriorating situation in 1958 was aggravated by the running down of consumer stocks, and how far this affects the situation in 1958 depends on the view taken by consumers as to the likely trend in consumption, prices and delivery times. The Iron and Steel Federation, discussing the outlet in the January issue of *Steel Review* says, "it seems reasonable to hope that by the middle of 1959, the Government measures to reactivate the economy will be favourably reflected in orders for steel. By then the recovery in the United States may be further under way and the recession in Europe halted, with beneficial effects on the primary producing countries' purchasing power and so on British exports. Such a development would pave the way for the re-expansion of steel production."

Most of the measures of relaxation taken by the Government, such as the lifting of hire purchase restrictions, will mainly stimulate demand for durable consumer goods. The first effect will be the clearing of stocks of such goods, and if the process goes far enough there will be increasing demands for light rolled products, which are easy in supply, and sheets, which are not. It is expected, however, that by the middle of the year there will be a substantial increase in wide strip mill capacity, as a result of improvements and extensions at the three existing strip mills at Ebbw Vale, Margam, and Shotton.

The main influence in the 1958 decline in steel consumption, however, seems to have been the drop in capital expenditure on fixed investment. A recent Board of Trade inquiry brought out the fact that manufacturing industry is likely to invest 16% less in 1959, and although public expenditure on new roads, educational buildings, etc., will increase, steel requirements may well decline. Thus, the completion of the railway wagon programme alone will mean a drop in steel demand greater than the total steel requirement of the Government's road programme for the next five years. The Federation believes there is a strong case for taking the opportunity of spare capacity in the capital and basic industries to encourage investment for improvement of efficiency and lowering of costs. It is suggested that investment allowances should be reintroduced, thereby removing, in part at least, the impediment to investment resulting from the inadequacy of depreciation allowances based on historical cost.

The Federation points out that the present underemployment of capacity "cannot leave the industry's long-term development unaffected". Its expansion plans were based on an estimate that the demand for steel would reach 29 million tons by 1962. That is now unlikely, and there may be a period of lower capital expenditure in the mid-1960s, when the Newport and Ravenscraig strip mills will be coming into operation.

Meeting Diary

13th January

Institute of Metals, South Wales Local Section. "The Zinc Blast Furnace", by S. W. K. MORGAN. Department of Metallurgy, University College, Singleton Park, Swansea. 6.30 p.m.

Sheffield Metallurgical Association. Annual General Meeting of the Refractories Group and Presidential Address by the New Chairman. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

14th January

Institute of Marine Engineers, Scottish Section. "Research and Failures of Metals in Service", by C. E. PHILLIPS and A. C. Low. 39, Elmbank Crescent, Glasgow, C.2. 7.30 p.m.

15th January

Institute of Fuel, Midland Section. "Fuel Efficiency and Measuring Techniques in a Steel Works", by R. MAYORCAS. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2. 6.30 p.m.

Institution of Mining and Metallurgy. "The Production of Copper and Sulphur by the Electro-Decomposition of Cuprous Sulphide", by Dr. T. P. HOAR and Dr. R. G. WARD; and "Equilibrium Measurements between Carbon-Saturated Mn-Fe-Si Melts and CaO-Al_2O_3-MnO-SiO_2 Slags", by Dr. E. T. TURKDOGAN and R. A. HANCOCK. Geological Society, Burlington House, Piccadilly, London, W.1. 5 p.m. Tea from 4.30 p.m.

Leeds Metallurgical Society. "The Ultimate Structure", by T. J. PARRY and S. NEWTON. Lecture Room C, Chemistry Wing, The University, Leeds, 2. 7.15 p.m.

16th January

Society of Chemical Industry, Corrosion Group. Joint Meeting with Glasgow Section and R.I.C. "Protection of Motor Vehicles from Corrosion", by S. G. CLARKE. Royal College of Science and Technology, Glasgow. 7.15 p.m.

West of Scotland Iron and Steel Institute. "The Propagation of Cracks", by W. MACFARLANE. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

19th January

Institute of Marine Engineers, West of England Section. "Welding in Marine Engineering", by J. A. DORRAT. Smith's Assembly Rooms, Bath. 7.30 p.m. All visitors welcome.

Sheffield Society of Engineers and Metallurgists Annual General Meeting and Presidential Address. The University Building, St. George's Square, Sheffield. 7.30 p.m.

20th January

Sheffield Metallurgical Association. Association's Annual General Meeting and Presidential Address. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

21st January

Institute of Metal Finishing, Organic Finishing Group. "The Applications of Plastic Coated Steel Sheet", by W. E. MARTIN and F. H. SMITH. Exchange and Engineering Centre, Stephenson Place, Birmingham, 2. 6.30 p.m.

Manchester Metallurgical Society. "The Investigation of Metallurgical Failures in Aircraft", by D. A. RYDER. Manchester Room, Central Library, Manchester. 6.30 p.m.

22nd January

Institute of Metals, Birmingham Local Section. "Mechanism of Solidification of Cast Iron", by H. MORROGH. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2. 6.30 p.m.

Institute of Metals, Sheffield Local Section. Research Topics. Engineering Lecture Theatre, The University, St. George's Square, Sheffield, 1. 7.30 p.m.

Society of Chemical Industry, Corrosion Group. Conversazione. Battersea College of Technology, Battersea Park Road, London, S.W.11. 6.30 p.m.

27th. January

North East Metallurgical Society. "Some Characteristics of High Strength Aluminium Alloys", by G. GODDARD. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.15 p.m.

Sheffield Metallurgical Association. "The Chlorination Method for the Separation of Inclusions, with particular reference to the Determination of Oxygen", by F. J. ARMSON. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

28th January

North East Coast Institution of Engineers and Shipbuilders. "The Use of Welding in Ship Repair Work", by A. BOWMAN. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 6 p.m.

30th January

Manchester Association of Engineers. "Powder Metallurgy", by DR. L. HARRISON. Engineers' Club, Albert Square, Manchester. 6.45 p.m.

Women's Engineering Society, London Branch. "Some Uses of Electron Beams in Metallurgy", by MRS. I. H. HARDWICK. Hope House, 45 Great Peter Street, Westminster, London, S. W.1. 7 p.m. Tea will be served at 6.30 p.m.

3rd February

East Midlands Metallurgical Society. Members' Night. Short papers by members. Electricity Lecture Theatre, Carrington Street, Nottingham. 7.30 p.m.

Institute of Metals, Oxford Local Section. "New Metals: The Rare Earths", by PROF. A. D. MCQUILLAN. Cadena Café, Cornmarket Street, Oxford. 7 p.m.

Institute of Metals, South Wales Local Section. "Progress in the Metallurgy of Deep Drawing and Pressing", by DR. D. V. WILSON. Department of Metallurgy, University College, Singleton Park, Swansea. 6.30 p.m.

Sheffield Metallurgical Association. "The Production of Heavy Castings", by J. H. PEARCE. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

4th February

Institute of Fuel. "A Radio-active Corrosion Probe", by D. ANSON. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m. (tea 5 p.m.).

Manchester Metallurgical Society. "Micro-Mechanism of Fracture", by PROF. W. S. OWEN. Manchester Room, Central Library, Manchester. 6.30 p.m.

5th February

Institute of Metals, Birmingham Local Section. Students' Evening. College of Technology, Gosta Green, Birmingham. 6.30 p.m.

Institute of Metals, London Local Section. "Metallurgical Information", by B. FULLMAN. 17, Belgrave Square, London, S.W.1. 6.30 p.m.

9th February

Institute of Metals, Scottish Local Section. Lecture by PROF. J. G. BALL. Details to be announced. Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

10th February

Sheffield Metallurgical Association. "Refractories and the Oxygen Steelmaking Process", by J. L. HARRISON and D. W. N. PITTS. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

11th February

Institute of Fuel, North-Western Section. "The Operation of Calder Hall", by J. GAWTHROP. Engineers' Club, Albert Square, Manchester, 2. 2.30 p.m.

Society of Chemical Industry, Corrosion Group. "Recent Research on the Corrosion of Tinplate' by S. C. BRITTON and K. BAIGHT. 14, Belgrave Square, London, S.W.1. 6.30 p.m.

12th February

Leeds Metallurgical Society. "Operational Research in the Steel Industry", by D. JORDAN. Lecture Room C, Chemistry Wing, The University, Leeds, 2. 7.15 p.m.

Liverpool Metallurgical Society. "The Russian Steel Industry", by R. WILCOCK. Joint Meeting with the Iron and Steel Institute. Library, Dept. of Metallurgy, The University, 146, Brownlow Hill, Liverpool, 3. 7 p.m.

13th February

West of Scotland Iron and Steel Institute. "Operational Research with particular reference to Open-Hearth Charging", by R. H. COLCUTT. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

Rolling Medium Width Steel Strip

Steel, Peech and Tozer's Brinsworth Mill

SINCE the end of the war, the demand for flat rolled products—plates, sheets and strip—has been increasing faster than that for other steel products. Among the reasons for this trend are rising living standards—which create a demand for motor cars, refrigerators, canned foods and other commodities which utilise flat steel products—and developments in fabricating techniques, such as welding, pressing and forming.

Hot rolled strip has been produced at the works of Steel, Peech and Tozer for many years. The Templeborough hot strip mill was laid down in 1920-21 and continues to give good service today; but the maximum strip width it is capable of rolling is 9 in., and site limitations make it difficult to carry out any extensive enlargements and modernisation. It was therefore decided that any increase in capacity would have to be achieved by erecting a completely new mill. Market research was carried out by the commercial research department of The United Steel Cos., Ltd., to determine the size of the potential market and the maximum width of strip which the mill should be capable of rolling. At the same time, members of Steel, Peech and Tozer's staff were studying the latest developments in strip mill design in Europe and the United States.

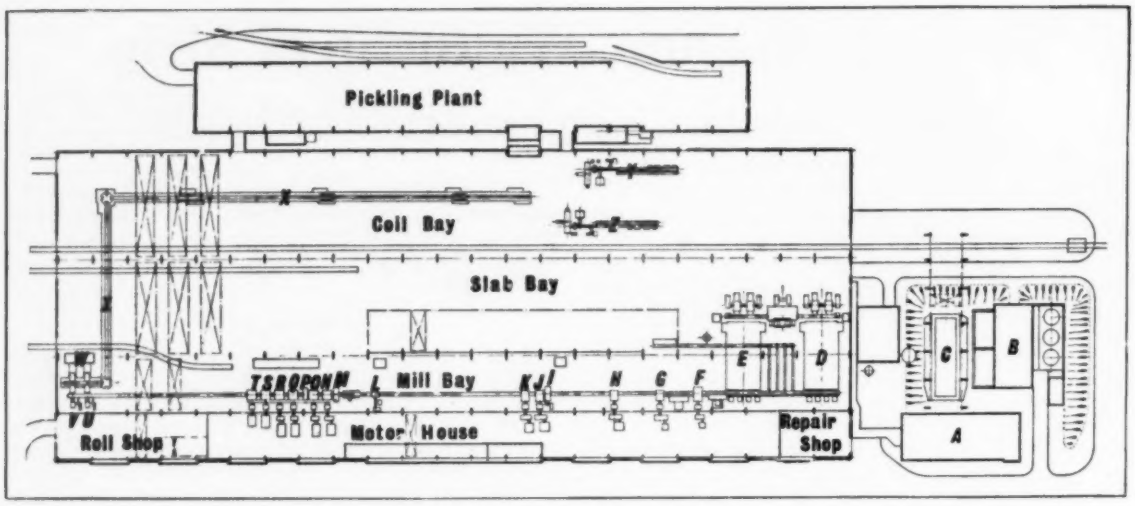
When the results of the market research and technical investigations had been correlated, the final choice was for a highly-mechanised continuous hot strip mill capable of rolling mild, carbon and special steels up to 18 in. wide, thus bridging the gap between the outputs of the narrow and wide strip mills now operating in this country. The mill which was selected will have an ultimate capacity of the order of 8,000 tons per week. It is capable of rolling strip from 4 in. to 18 in. wide, with a maximum thickness of 0·25 in. and minimum thickness, according to width, of 0·060 in. (16–18 in.), 0·056 in. (12–16 in.), 0·048 in. (7–12 in.), and 0·042 in. (4–7 in.), and its design is such that it will set new standards for close tolerances and surface finish. The embodiment of all these plans reached a final form in the autumn of 1957, when the Brinsworth mill was commissioned. It has cost over £4 million.

Steel Supplies

Before the mill reached the drawing board, however, a number of vital decisions had to be made concerning the provision of adequate steel supplies to maintain it at a high level of production. The first consideration was that of steel melting capacity. Several years ago, a new melting shop was built at another United Steel branch—Appleby-Frodingham Steel Co., in Scunthorpe—where allowance was made for the addition of further open hearth furnaces, as and when this became necessary. The Brinsworth mill gave the impetus to this further development, and a new 300-350-ton open hearth furnace was laid down and commissioned at the end of 1956.

Ingots from this furnace are delivered to the Rotherham works in special cars constructed by British Railways for the purpose. An average of almost 10,000 tons of steel a month will ultimately be obtained in this way. In order to process the additional quantity of ingot steel, it was necessary to improve the heating capacity of the existing soaking pits, and step up substantially the throughputs of the cogging and slab mills. This has now been accomplished. In the case of the cogging mill, it involved the complete replacement of the motor-generator set and main mill drive. The 30 in. semi-continuous slab mill has been modernised, involving new main roller tables, hydraulic side guard manipulators on both sides of the mill, and a new 800-ton shear with the appropriate run-out tables and cooling beds.

General view of the mill bay, showing mill stands on left and control pulpits on right.



Layout of Brinsworth mill.

Site Preparation

Many years ago, with an eye to possible future developments, Steel, Peech and Tozer purchased a large tract of land on the south side of the Sheffield Road, opposite the company's Templeborough works. As the broad outlines of the Brinsworth mill scheme began to take shape, part of this land was earmarked as the location for the new project. Bulk excavation on the site began in early August, 1955. It entailed the removal of some 350,000 cu. yds. of soil, shale and soft rock, the foundations for the mill building and substructure being taken down to rock level—about 12 feet below the original surface at the western end of the building. In order to connect the mill with the existing works' sidings, which are about half a mile away, it was necessary to drive a deep railway cutting through a hillside at the Rotherham end of the site. Before this was attempted, however, a 150 ft. long reinforced concrete road bridge was built across the intended path of the cutting, involving the construction of foundations at the bottom of 24 ft. deep holes and the erection of the piers and bridge. Existing 30 in. and 18 in. water mains and high tension cables were diverted to run under the surface of the bridge.

Mill Building

By the beginning of 1956, foundation work for the main mill building was well advanced, and erection of the 3,400 tons of structural steelwork began. The structure includes substantial quantities of castellated open web beams. The building has an overall length of 800 ft. and is approximately 300 ft. wide. Its front elevation —facing the Sheffield-Rotherham Road—consists of rustic brickwork alternating with deep panels of glazing, giving a pleasing, modern appearance. The back and sides of the building are almost entirely sheeted with protected metal, the roof being formed of "Q" decking and incorporating adequate ventilators which give it a distinctive high-low aspect.

The mill is divided longitudinally into four bays. Nearest the front elevation is the motor room, an extension of which forms the roll preparation bay. Then comes the main mill bay, followed by the slab storage and conditioning bay and the coil storage and despatch bay.

General view of the motor room from the roughing stands end.

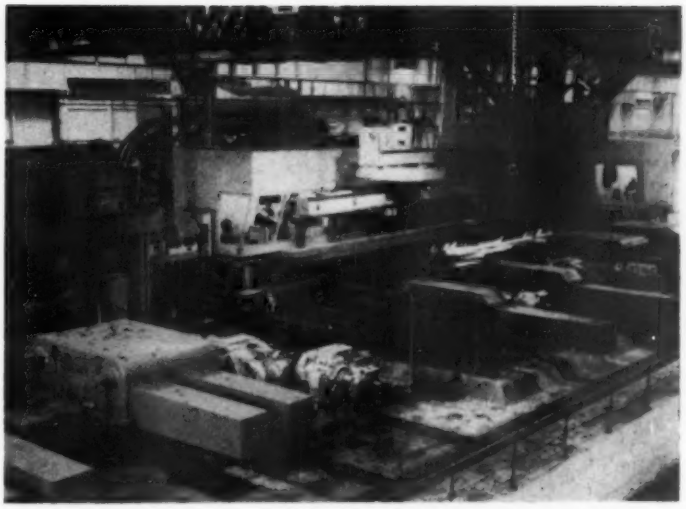
Motor Room

The English Electric Co., Ltd., was the main contractor for almost the whole of the electrical equipment driving the Brinsworth mill. One of the most interesting features of the mill is that it is rectifier fed, the electrical feed to the main drive D.C. motors being converted from A.C. by a bank of rectifiers. The number of rotating machines is therefore

reduced and such heavy foundations are not required, thus reducing the initial costs and maintenance. The main drives, rectifiers, and control gear are housed in the main motor room, with the auxiliaries on the mill floor and in the basement.

Main Drives

The roughing train, as its name implies, takes the first few heavy reduction passes; this results in the first stands being on load for short high-peak periods. Economically, the most satisfactory method of driving such stands is to use a slip-ring induction motor in conjuction with a flywheel, which absorbs energy from the motor during high-load periods and supplies it to the mill during rolling. This has been adopted in the case of the horizontal edger and the first roughing stand drive. The necessary motor speed droop on load, permitting the flywheel to give up its energy, is obtained by means of a fixed slip resistor on the horizontal edger and and an automatic slip regulator on the first roughing stand where the longer passes require a more uniform control in comparison with the horizontal edger.



The charging side of the reheating furnaces, showing the slab depiler and furnace pushers.

Roughing stands Nos. 2 and 3 are each driven by a salient-pole synchronous motor designed for working peaks of 2·5 × full-load torque to meet heavy rolling duty requirements. The two machines are reactor started and are each fitted with automatic unity-power-factor control, preventing heavy lagging reactive kVA. demands being made on the supply during rolling.

The second of these drives is close-coupled by the strip to roughing stand No. 4. Roughing stand No. 3, being synchronous-motor driver, is a "hard" drive, i.e. having no speed droop with load. Control must be available therefore on roughing stand No. 4 to allow for the change in draftings of the mill, and this stand is accordingly driven by a 1,200 h.p. D.C. motor with variable speed-setting control, and individually fed from a 1,000 kW., 600 volt grid-controlled rectifier bank.

The stock, having passed through the roughing train, is held by the shear operator on the delay tables until it has cooled to the correct rolling temperature and is then allowed to enter the six-stand finishing mill. The first four stands are individually driven through gears by 600 volt D.C. variable-speed motors, the last two being directly driven. The D.C. supply for the motors is supplied from two 3,500 kW. rectifier banks, equipped with grid control for starting and voltage holding.

Two edgers are included in the finishing mill train, one in the front of the first stand, the second after stand No. 2. To ensure that speed differences between the edgers and the main drives neither damage the strip nor overload the edger drives, the control is arranged for the edger motors to have a 20% regulation characteristic throughout the speed range.

Rectifiers

The total installed rectifier plant is 9,000 kW., and comprises twenty-four English Electric steel tank mercury-arc converters, grouped according to the size and duties of the various drives. To allow maximum accessibility for maintenance of the equipments, the rectifier tanks are trolley mounted. They are installed behind shallow cubicles which house all the associated auxiliary equipment, the cubicles forming a rectifier enclosure within the motor room. Temperature control of the rectifier equipment is extremely important and a thermostatically-controlled ventilation system has been installed within the enclosure.

Control

Master and supervisory control of the main drives for both roughing and finishing mills is carried out from open-type boards with all the components mounted on polished slate panels. Associated with the control boards are the 400 cycle magnetic amplifiers. These are chassis mounted units fitted into cubicles with full monitoring of reference and output windings. All control of main drives and a large percentage of auxiliaries is carried out from pulpits designed for seated operators overlooking the mill.

Slab and Main Mill Bays

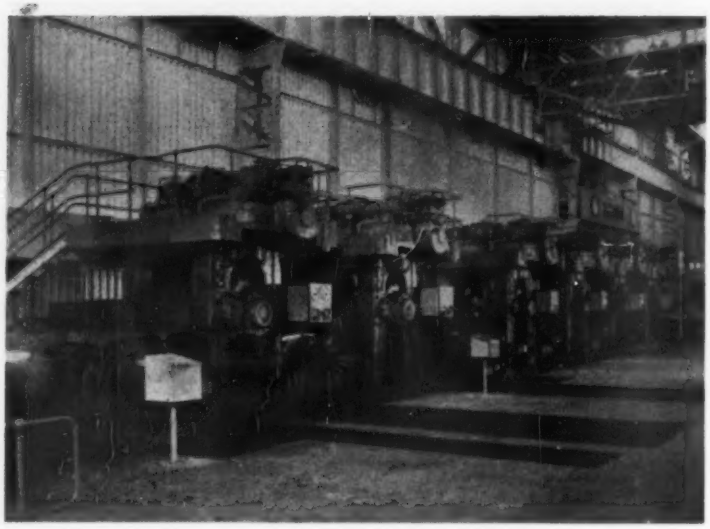
Slab Handling

At the Rotherham end of the 96 ft. wide slab bay, two rail tracks enter the building for the transport of slabs from the Templeborough works. Here, the slabs are unloaded and examined, any surface defects being removed. A semi-portal crane is provided for handling the slabs, which have a maximum length of 28 ft. 6 in., 3 in. thickness and 18 in. width. In addition to the 5-ton semi-portal crane, the bay is served by three 15-ton overhead cranes, equipped with lifting beams.

The main mill bay contains the heart of the installation —the Loewy continuous rolling mill and its associated reheating furnaces.

Reheating

From the slab bay, slabs are placed on the grid of a depiler, which incorporates a 30-ton weighing machine. This depiler is situated centrally between the two reheating furnaces, the slabs being fed singly onto either of two furnace charging roller tables.



The finishing train with its six rolling stands and two vertical edgers.

The two Stein and Atkinson continuous reheating furnaces are of the end charging and discharging type, the slabs being pushed through the heating zone by means of electrically-operated pushers. They are of the Rust zone-fired design ; each furnace has two zones—tonnage and soaking—and the soaking zone is, in turn, divided into three sections across the furnace for control purposes.

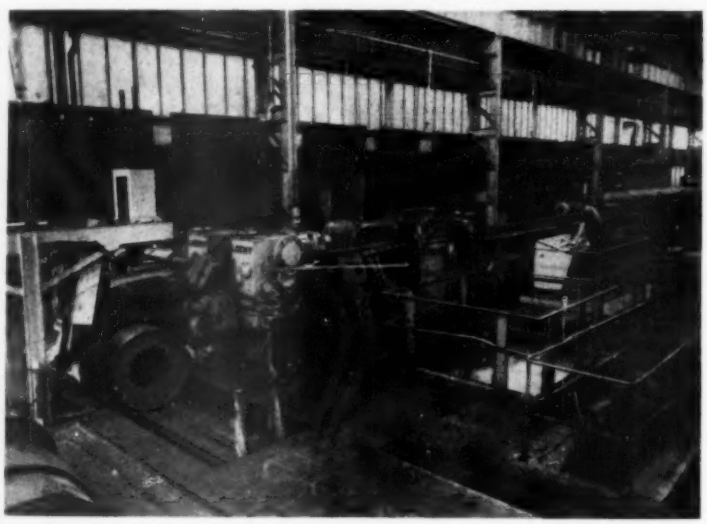
The well-established conception of zone-firing permits the heating of the steel to be carried out separately from the final conditioning. The main heating is carried out in the tonnage zone, which is regulated according to output required. In the soaking zone, little heat is added to the steel, but it is operated so as to produce a slab at the point of discharge at uniform temperature with a scale which is easily removed in the mill. The division of the soaking zone into three is due to the width of the furnace, and gives very precise control of temperature over the whole slab length.

The furnace length is 60 ft. from charging door to apex of discharge slope, and the width 31 ft. 6 in. inside walls. The design provides for heating slabs up to 29 ft. long, and up to 3 in. thick, varying from 5 to 20 in. in width. Alternatively, double rows of half length slabs may be charged. The nominal output of each furnace, heating slabs of this size, is 60 tons per hour, but combustion equipment is provided so that outputs of up to 75 tons per hour may be obtained. The furnaces are fired with heavy fuel oil, and the Rust back-atomising burner is used on both zones, together with a specially designed air-throat which ensures good distribution of air around the oil atomiser, and also equal distribution of air from burner to burner. The burners are steam atomised at pressures of the order of 60–70 lb./sq. in. Nine burners are provided in the heating zone and twelve in the soaking zone.

Combustion air for each furnace is supplied from a fan and preheated in a Schack flue tube type recuperator. The recuperator consists of a single tube bundle, the waste gases passing through the tubes while the combustion air passes over the outside of the tubes in a counter-flow direction. The recuperator is supported from the upper end, freedom of expansion being allowed at the lower end. The flues from the furnaces pass underground to a house outside the mill building which accommodates the waste gas fans and one of the combustion air fans. Suitable by-pass flues with shut-off dampers enable the waste gases to be taken directly from the furnaces to the chimney, if necessary. The dampers are of the Javelle type, sliding in guides.

The furnaces are encased in mild steel plates and bound in heavy rolled steel sections, providing a structure designed to prevent distortion. The refractory qualities in hearth, walls and roof have been carefully selected to give long trouble-free service: the roof is of the Detrick Detred suspended design. Heavy hydraulic grade skids are provided at the charging end of the furnace, over which the slabs ride.

For control purposes, each furnace is divided into four zones, the tonnage zone and the three-section soaking zone. On each zone there is temperature control, and air/oil ratio and oil/steam ratio control, the temperature controller resetting the control index of air, oil and steam flow controllers. All metering is transmitted from the point of measurement, air being metered for control on the hot side of the recuperator. Total air is metered on the cold side for check purposes. In addition



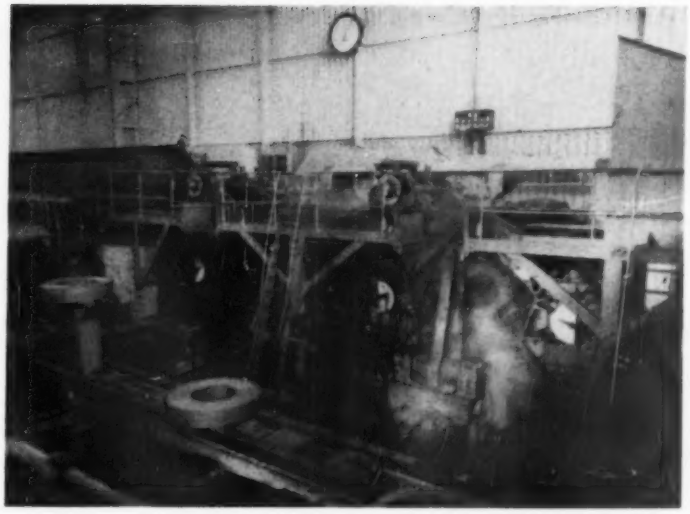
One of the two shearing lines, comprising a decoiler, an edge trimming shear, a roller flattener combined with a flying shear, a piling device, and a 10 ton weighing machine.

combustion air pressure is controlled before distribution to the zones and furnace pressure via a damper set between the recuperator and the waste gas fan.

A 135 ft. long live roller table extending across the discharge end of the two furnaces, takes slabs to the first section of the mill. If a slab has to be diverted from the mill on emerging from the furnaces to a discharge table, it is conveyed to a section of the table between the two furnaces. Here, the slab can be positioned and then conveyed by means of a slab transfer to a roller table and so back into the slab bay.

Roughing Stands

The first section of the mill consists of a horizontal edging and scale-breaking stand, with 24½ in. diameter rolls of 31 in. barrel length, driven by a 350 h.p. A.C. motor through a flywheel-assisted reduction gear. The horizontal edger is equipped with manipulators on the ingoing side to turn the slabs on edge, while further manipulators on the outgoing side turn the slabs back ready for entry into the first roughing stand.



The two down-coilers and the start of the coil conveyor system.

The roughing train comprises four two-high mills having 21 in. diameter rolls of 24 in. barrel length. Preceding No. 3 rougher, there is a 26 in. vertical edging stand. Between stands Nos. 1 and 2 there is a free run of 38 ft., with a 63 ft. run between stands Nos. 2 and 3. Stands Nos. 3 and 4 are close-coupled. No. 1 stand of the roughing mill is driven by a 700 h.p. A.C. motor through a flywheel-assisted reduction gear unit, Nos. 2 and 3 stands by 1,200 h.p. A.C. synchronous motors, and No. 4 stand by a 1,200 h.p. D.C. motor.

A centralised oil lubrication system supplies the main gearbox and pinion stands of the roughing train, a visible and audible alarm system operating automatically if the oil pressure falls below a predetermined limit. All the stands in this train are equipped with totally-enclosed, water-lubricated fabric bearings.

From the roughing mill, the stock travels along a 150 ft. long delay table before passing a rotary flying shear, which can be used for either end trimming, or emergency shearing in the event of "cobbles" in the finishing train.

Powered by a 300 h.p. D.C. motor, the shear can cut hot strip up to 1 in. thick and 18 in. wide travelling at a speed of up to 450 ft./min.

Finishing Stands

The finishing train of the strip mill has six four-high rolling mill stands and two vertical edgers. Both edgers are driven by 75 h.p. motors, the first being situated in front of No. 1 finishing stand, and the second between Nos. 2 and 3 finishing stands.

Each of the six finishing stands has 14 in. diameter work rolls and 23 in. diameter back-up rolls, all being of 23 in. barrel length. The mill stands are equipped with electric screwdown gear, the work rolls being mounted on tapered roller bearings, and the back-up rolls on multi-roller cylindrical type bearings. Lubrication of the bearings is carried out by means of an automatic pumping system. A centralised oil lubrication system, similar to that installed on the roughing mill, supplies the main gearbox and pinion stands. Stand No. 1 is driven by a 1,200 h.p. D.C. motor, Nos. 2, 3, 4 and 5 by 1,750 h.p. D.C. motors, and No. 6 by a 1,200 h.p. D.C. motor.

By the time the strip reaches the last finishing stand, it is travelling at up to 3,000 ft./min. and proceeds along a 160 ft. cooling table where a bank of water sprays can be used if more rapid cooling is required. Next, the strip is coiled on either of two 20 in. diameter horizontal down-coilers, each operated by 175 h.p. D.C. motors. The coilers, each with collapsing mandrel and nine driven guide rollers, automatically form a tight and even coil at speeds up to 3,200 ft./min. with no deformation of the strip due to hammering. Completed coils are ejected from the coiler drum and placed on a conveyor for onward transmission to the coil storage and despatch bay.

Measurement of Temperature and Dimensions

During the actual rolling process, continuous measurements of the temperature, width and thickness of the strip are taken. The temperature is measured at four points and recorded on large circular indicators which are clearly visible to the mill operatives.

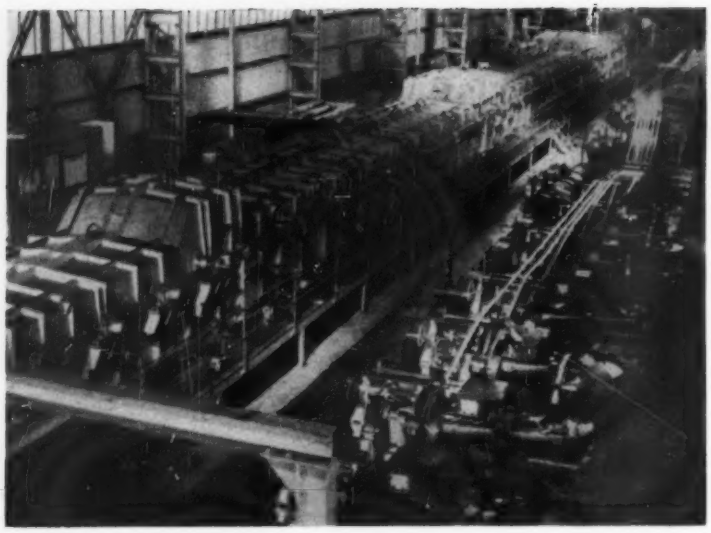
Strip width is measured between the last finishing stand and the coilers by means of a photo-electric telescope system mounted above the cooling table, deviation of the actual width from the desired width being indicated in a similar manner to the temperature readings.

Thickness measurement is also obtained by non-contact means, employing a radioactive source positioned beneath the strip and a detector unit above the strip. The intensity of radiation reaching the detector varies with strip thickness, the variations—after passing through electronic equipment—being displayed pictorially on a large lamp display board on the motor room wall. A more permanent record is transmitted to a teleprinter in the finishing mill pulpit.*

Coil Bay

The 600 ft. long coil conveyor runs underneath the slab bay and emerges down the middle of the coil bay, where the coils can be lifted by magnet crane and placed

* Method used at Templeborough strip mill. S.: METALLURGIA, **55**, 241–245.



The two multi-strand pickling lines housed in a separate building.

in storage while cooling. The conveyor operates at a speed of 30 ft./min. and can handle coils weighing up to 5,600 lb. It incorporates a 3-ton weighing machine, fitted with chart and card punch recording equipment.

There are two shearing lines, each comprising a decoiler, an edge trimming shear, a roller flattener combined with a flying shear, a piling device and a 10-ton weighing machine. They are capable of shearing strip up to 18 in. wide and 0·08 in. to 0·25 in. thick in maximum lengths of 30 ft. A separate inspection line is installed at the Rotherham end of the bay, where strip up to 19 in. wide and from 0·042 in. to 0·25 in. thick can be gauged and inspected. The line includes a hydraulic shear for removing faulty material and can produce small coils of strip, if required.

A railway dock extends the full length of the bay, adjacent to the slab bay, and road transport can obtain access at both ends of the bay for the despatch of finished products. Three 10-ton overhead cranes serve the coil bay.

Pickling Plant

As a proportion of the hot rolled strip is pickled before despatch, a separate building, 550 ft. long by 66 ft. wide, has been built alongside the main building to accommodate two multi-strand pickling lines with appropriate ancillary equipment. Here the scale is removed by a combination of mechanical and chemical means. The strip is uncoiled and fed between staggered steel rolls which bend it sufficiently to break up the hard, loosely adhering scale. The strip then passes through a tank of dilute sulphuric acid to remove the remainder of the scale, the acid being removed in hot and cold water tanks. Finally, the strip receives a coating of soluble oil before recoiling. Acid recovery and neutralisation plants are located on an adjacent site away from the pickling plant itself.

Mill Services

Water

Water requirements for descaling, roll cooling, strip pickling, etc., amount to approximately 600,000 gallons per hour. Part of this water is filtered and recirculated, and the remainder, such as that used for roll cooling, is given ample settling time in a large scale pit before being recirculated. There are five distinct pumping systems for furnace cooling, roll cooling, delay table and fabric bearings, scale flushing, and run-out table and coilers, respectively.

High pressure descaling water is taken from the make-up supply after filtration. Make-up water, amounting to 5%, or 30,000 gallons per hour, is taken from the rising main supplying the main works filtration plant at Brinsworth, the water in the rising main being taken direct from the River Don.

Scale Pit

Adjacent to the Sheffield end of the mill building is the scale pit, measuring 80 ft. long by 20 ft. wide by 50 ft. deep. Water employed in the roll cooling, fabric bearing cooling, delay table, and scale flushing systems returns by gravity to the scale pit, where the scale is allowed to settle out.

Steam, Oil, Gas, etc.

Service pipes carrying steam, oil, coke oven gas, water and compressed air from the company's Templeborough works across the Sheffield Road are contained in a quarter-mile long service tunnel, 8 ft. 6 in. in diameter. The pipework includes 7 in. bore steam mains, 4 in. bore oil mains, 2 in. bore gas piping and 4 in. bore water mains. A compressed air main runs between the Brinsworth mill compressor house and the Templeborough melting shop.

Inside the mill building, the reheating furnaces are supplied from 2½ in. bore steam and oil mains, while 4 in. to ¾ in. bore gas, compressed air and water mains serve the strip mill. A 6 in. bore process steam main runs to the pickling tanks, heat exchanger, regenerated acid tanks and shop space heating system.

Communications

Rapid dissemination of information is vital to the efficient operation of a modern, high speed rolling mill. Accordingly, the Brinsworth mill is equipped with a number of devices designed to meet this objective. The inter-communication system comprises microphones and loudspeakers at strategic points throughout the building; the main mill system has twenty-eight key points, any one of which is in direct and immediate contact with all the others. In addition, two small inter-communication systems are provided for the furnace pusher and mill record system, respectively. General messages can be broadcast from eight positions over a loud hailer system, thus enabling contact to be maintained with mill personnel who are not normally working at a fixed point. The loud hailer system is also linked up with the inter-communication network.

Information required for the mill records is conveyed by means of teleprinters, which enable each slab to be individually identified and followed through from the slab bay to the coil weighing machine. Finally, there is a pneumatic tube system in operation. Internally,

this is utilised for passing messages between the slab bay and the re-heating furnaces and between the furnaces and the coil weighing machine. Externally, there is a pneumatic tube link with Templeborough works.

Centralograph

The Centralograph is a recording instrument for the centralised registration of the production performance of up to twenty machines. During normal production, detecting contacts on the machines transmit electrical impulses to the Centralograph, which are recorded as short horizontal lines on a time-referenced diagram called a centralogram. Divided into twenty columns to represent the machines, the diagram shows at a glance the machine time (horizontal lines) and the idle time (blank spaces).

The reasons for stoppages are reported manually on a dial located near each machine, and are recorded on the centralogram in the form of a numeral at the side of the line registration. Each numeral corresponds to a certain reason for stoppage, according to a predetermined code.

In the Brinsworth mill, Centralograph control points are situated at desired positions from the furnaces through to the coil bay shearing lines. By analysing the centralogram, valuable data is obtained on the duration and frequency of stoppages, enabling suitable adjustments to be made to the planning of the work flow.

Retirement of Dr. J. G. Pearce

THE Director of The British Cast Iron Research Association, Dr. J. G. Pearce, C.B.E., retired from office at the end of 1958. The British Cast Iron Research Association was founded in 1921 and Dr. Pearce had held the post of Director since 1924.

The period 1924–1958 has been one of marked growth and change, not only in the research association, but also in the ironfounding industry that it serves, which in recent years has had an output of castings approaching four million tons a year. These years have seen a steadily continuing improvement in the control, the quality, and the strength properties of the foundry product, reflected in successive up-gradings in the minimum standard requirements for iron castings. This general overall improvement is perhaps more significant, though less spectacular, than the extending range of new cast iron materials with impressive engineering properties, and the many new production processes introduced during this period. These improvements are almost certainly due in considerable measure to the research body and to its retiring head, and the industry has shown its appreciation and awareness of this fact by its progressively increasing support. B.C.I.R.A., which in 1924 numbered a staff of about 12 and had an income of the order of £5,000, now has a staff of 150 and an income provided by industry and the Department of Scientific and Industrial Research of about £200,000.

Dr. Pearce is internationally known and respected wherever ironfounding is practised. He is a graduate of Birmingham University and among other distinctions he holds an honorary doctorate (D.Ing.) from the University of Aachen, awarded in 1948. He received the O.B.E. in 1950 and the C.B.E. in 1957. He has been a member of the Worshipful Company of Founders since 1935 and the Livery recently conferred on him the Founders' Medal for services to the art and mystery of ironfounding.

Earlier, Dr. Pearce was associated with Sir Arthur Fleming in the planning and organisation of the Research and Education Department created by the Metropolitan-Vickers Electrical Co., Ltd., in Manchester, and he was co-author with Sir Arthur of two textbooks on apprentice training and research in industry. He has written and lectured widely both in Europe and the U.S. His interest in education made him active in promoting the British Foundry School in 1935. This was reconstituted in 1948 at Wolverhampton as the National Foundry College : Dr. Pearce is Vice-Chairman of the Board of Governors and President of the Foundry Technical Group, an association of the College's former students. When the present academic year is completed, the number of diploma holders will be of the order of 250, of whom 40 came from overseas, two-thirds of them from the Commonwealth.

Dr. Pearce has served on numerous national and international committees : since 1935 he has been Chairman of the Main Committee on Cast Iron of the British Standards Institution, and he is Chairman of the appropriate cast iron committee of the International Standards Organization, which had its first meeting in London in 1955.

A dinner to mark his retirement was given to Dr. Pearce at the Connaught Rooms, London, W.C.2., on Monday, December 15th, at which many old friends and representatives of the ironfounding industry were present.

Aluminium Production Reduced

PRODUCTION of primary aluminium at the Canadian smelters of Aluminium, Ltd., is to be reduced by about 10% to an annual rate of approximately 500,000 tons, as compared with production of 620,000 tons in the peak year 1956. With several months inventories in reserve, the cutback is expected to bring rates of production into approximate balance with the current and estimated near-term volume of sales of Canadian ingot. The reduction in output will be made early in January at two plants in Quebec, and it is expected that the power released will be sold and may be reclaimed for metal production at any time.

New Standard for Wire Brushes

AN announcement from the British Standards Institution recalls that a new British Standard (B.S. 2939) was published in January 1958, primarily to assist local authorities and hospitals to procure good quality brushes in a comprehensive range of sizes. It is, however, pointed out that several manufacturers in the industry are still receiving orders referring to the old War Office Specification TG 26. This has in fact been superseded by B.S. 2939, which also includes specifications for many brushes not previously standardised. It would be helpful to all concerned if purchasing officers would familiarise themselves with the terms of the new standard and use it as a reference point when they are in the market for new brushes.

Maunsel White

An Early Worker on High Speed Steels

By Eric N. Simons

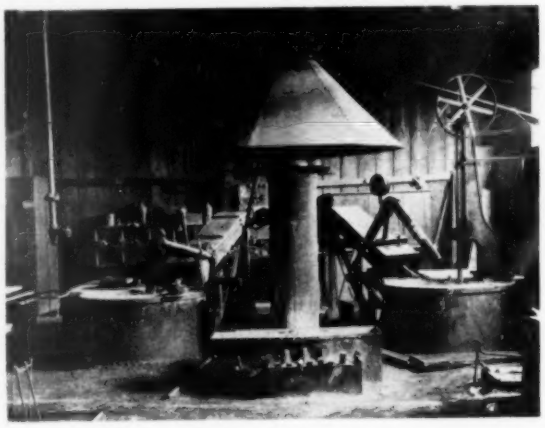
There is still a certain amount of controversy about the origin of high speed steel. In this article, the author refers to the work of Maunsel White in this field, carried out in collaboration with F. W. Taylor, but makes no attempt to discuss the rival claims.

WHO invented the modern high speed steels? Their forerunner was undoubtedly the celebrated Mushet self-hardening steel, and it is reasonably well-established that the advantages obtained when Mushet steel was subjected to an air blast for quenching were first observed at the works of Samuel Osborn & Co., Ltd. Apparently a number of different people claim to have made this discovery round about the same time, but this is unimportant.

Tungsten and other hardening elements besides carbon are known to have been present in steels of extremely ancient origin, and the tungsten-chromium-manganese steels that eventually became the modern high speed steels had been known for some years before Taylor and White discovered the "high heat treatment" which led to the large scale introduction of high speed steels into the machine shops of America. That F. W. Taylor and Maunsel White, his associate in the experiments that produced this result, had been largely anticipated by Sheffield steel manufacturers is not denied, but the Americans claim that while the Mushet experiments and recommended practice approximated closely to the Taylor-White discoveries, the "high heat treatment" was new. Mushet tools were but little used for increasing speeds, and their employment was usually to save regrinds or to machine work not machinable with carbon steel tools. Most users, they contend, failed to work Mushet steel tools at maximum efficiency.

Although the author was on friendly terms with Mushet's secretary and associate, long since dead, he does not attempt to discuss the rival claims. Sheffield steel makers had in the 'nineties a great passion for secrecy. Robert Woodward, for example, dissuaded Mushet from patenting his steel because that would be to tell the world how it was made. The Sheffield steel manufacturers probably knew all about hardening high speed steel, but kept their work dark, with the result that the publicity-minded Americans were able to "steal their thunder" and impress the world with the belief that Taylor-White high speed steels were the first of their kind. Certainly the author in his youth was always told that Taylor and White "invented" high speed steel, and in the "Encyclopedia Britannica," 13th edition, high speed steels are mentioned under the name "Taylor-White high speed steels," and no other.

The driving force in the invention of the Taylor-White high speed steels was unquestionably F. W. Taylor, an American economist, who as long ago as 1894 was experimenting with Mushet and other self-hardening steels as a means of improving workshop efficiency. He eventually



The laboratory in which Taylor and White began the series of experiments which led to the development of the Taylor-White high speed steels.

took charge of the Bethlehem steel works, where Maunsel White was chemist, and it was at these works that the soon world-famous high speed steels were developed. While Taylor supplied the drive and the initiative that brought their experiments to a successful conclusion, it is believed by many that the technical achievement was primarily the work of Maunsel White.

In comparison to Taylor, White has received little recognition, and there are few facts about him as a man. Indeed, the United States appears to have allowed his memory to fade until even the most careful investigation has produced little that brings him to life as a human being. He was born in Plaquemines, Louisiana, on October 22nd, 1856, and came of an illustrious family, being directly descended from the line of Jefferson Davis, the ill-starred President of the short-lived Confederate States of America. Jefferson Davis's sister was his maternal grandmother.

As the family was affluent, it was considered better that the boy should be educated at home, and he was accordingly instructed by a series of tutors in his father's house. That this tuition was adequate is sufficiently indicated by the admission of the young man to the University of Georgetown, near Washington, where he remained for a period of some years. His interests were predominantly technical, as were those of many young Americans in those days, and he decided upon a career in engineering.

Engineering Training

The next stage was, therefore, his entering the workshops of the Lehigh Valley Railroad at Weatherby, Pennsylvania. It was in these shops that he acquired an extensive knowledge of practical mechanics, but he appreciated that practical ability was not in itself sufficient. He decided to equip himself thoroughly for his chosen profession, and gave up work in the shops so as to enter as a student the Stevens Institute of Hoboken, New Jersey, in 1875.

Here he remained until 1879, when he graduated as a mechanical and civil engineer. Immediately after obtaining his diploma he was engaged by the Bethlehem Iron Company of Bethlehem, Pa. under John Fritz, and speedily acquired a reputation for efficient, loyal service, so that in 1893 he was placed in charge of the company's exhibit at the World Fair in Chicago, having previously been appointed chief of the metallurgical department.

Five years later, Maunsel White made the acquaintance of his new chief, F. W. Taylor, whose energy he appreciated and whose objectives had his whole-hearted co-operation. In the small laboratory shown in the illustration the two men began a series of careful tests to ascertain the best type of steel to be used throughout the works for cutting tools, and picked out one that, when it was correctly heat treated, they believed would cut faster than any of the others. They knew that a great saving in time and cost would be achieved if they could standardise on one steel for the entire works.

When they had made their choice, they called all the works foremen together to show them how much better the " standard " steel was than the others, and so obtain their co-operation. Unfortunately, the carefully ground, tempered and prepared tools, all of identical form, did not prove their point. The so-called " best " steel, on which the works was to standardise, was the worst of all.

This was a nasty blow for White and Taylor, and they imagined the cause to be defective heat treatment, so they set to work to find out what would happen if steels of the type chosen were heated at various temperatures, from a black heat up to a temperature higher than was considered in those days legitimate. In the end, they found that whereas it had been believed for centuries that steel must not be taken to a temperature above red heat, their tools could be hardened at temperatures little short of the melting point, and would cut better when so treated.

Nevertheless, the tools were even yet not so good as they wished. They gave a rough cut, and this led White to suggest that possibly a variation in the alloy content and in the types of alloys introduced might give a better result. They experimented, therefore, with varying proportions and varying kinds of alloys, and eventually produced their Taylor-White high speed steels, which, if previously anticipated by Sheffield steel makers, nevertheless captured the imagination of machinists all over the world.

The two men tried, like the Sheffielders, to keep their secret until they had perfected their work, but the success of their tools in the shops to which they sold the rights could not be hidden, and as a result steel makers all over Europe began to perfect the tungsten steels and widen their range of application.

Process Patented

In 1900, Maunsel White again represented the Bethlehem Steel Company at the Paris Exhibition, and the Administration in Paris presented him with the Bronze Medal of Merit as a result of the exhibit of his firm, which had been planned by him. Then, in 1901, he and Taylor patented their process under the title : " Metal Cutting Tool and Method of Making the Same " (No.668,270, 19.2.1901). This covers " A metal-cutting tool formed of air-hardening tool steel containing not less than 3% of chromium and in addition one or more of the other specified members of the chromium group in the proportion of not less then 6% of tungsten or its specified equivalent, said tool or its cutting portion being characterised, as described, by a considerable reduction of its contained carbide of chromium as compared with the steel from which it is made, and by its capacity to maintain its cutting edge in cutting the softer steels at temperatures at or verging on incandescence. . . heating said tool or its cutting portion to a temperature of not less then 1,850° F. . . . cooling the tool rapidly to a temperature below 1,550° F. . . . then reheating it to a temperature above 700° F. and below 1,260° F." Application for the Patent had been filed on October 20th, 1899.

The inventors claimed that " tools prepared and treated in this way have not only the capacity to work at much higher temperatures then has heretofore been practicable, but are distinguishable from tools not treated in accordance with our method by having a coarser and more crystalline grain in the steel, and by a considerable reduction in the proportion of carbide of chromium present in the treated steel as compared with that present in the untreated steel."

As an example of a steel composition giving excellent results in cutting very hard metal when treated by their method, they cite one in which the iron is associated with the following percentages of other elements : carbon, 1·85 ; chromium, 3·80 ; tungsten, 8·0 ; manganese, 0·30 ; silicon, 0·15 ; phosphorus, 0·025 ; sulphur, 0·030.

One authority writes : " Maunsel White will best be remembered through his part in the extended investigation which led to the discovery of the Taylor-White process of treating steel and the development of high speed tools, which have revolutionised the machine shop practice of the world. In general, he has been accorded the credit which belongs to him in the discovery of the process, but few have appreciated the detailed thoroughness of his work, that true scientific devotion which enabled him to plod along, month after month, developing methodically one fact after another, and the rare ability with which he was able, in the end, to co-ordinate and group these facts so as to indicate the conclusions and theories towards which they tended."

Colour-Temperature Relationship

In collaboration with Taylor, White also carried out an investigation into the relationship between the colour of heated steel and its temperature, and gave a short paper on this subject to the New York, December, meeting of the American Society of Mechanical Engineers in 1899. In this, he mentioned that different observers have a different eye for colour, which leads to quite a range of temperatures covering the same colour. He and Taylor had also found that the quality and intensity of the light in which the colour is observed influences the determination of temperature by eye. The two men had, therefore, adopted a nomenclature of colour scale with the corresponding determined values in deg. F. as best suited to the ordinary conditions met with in most

smiths' shops. The code is now of little importance, but the following sentence occurs in the paper and merits attention: "This demand for more accurate temperatures must eventually lead to the use of accurate pyrometric instruments." This written nearly sixty years ago, when there was only the Le Chatelier pyrometer available, was excellent foresight.

Authority on Armour Plate

While in the service of the Bethlehem Steel Company, Maunsel White frequently visited Europe on behalf of his employers, arranging among other things for the sale of great quantities of armour plate to the Government of Russia, through personal interviews with the ministers of the Czar, and at least one audience with the Czar himself. The confidence inspired by his metallurgical work was shown by the trust reposed in him by the government officials in America detailed to supervise the manufacture of armour plate and ordnance. His "O.K." on a piece of steel was regarded as final.

White's friends knew him as a man of rare versatility and catholicity of taste, with an intense love of literature and the arts and marked ability in these directions as well as in the realm of applied science. He was both a poet and a mathematician, a combination so rare that he was a marvel to all his friends. Alive to beauty, he could at the same time get at the kernel of a problem with rapidity, clarity and accuracy. His work at the Bethlehem Steel Company gained for him the friendship and admiration of John Fritz, then the "dean" of the steel industry in the United States. White was a life member of the American Society of Mechanical Engineers and a Member of the American Society of Mining Engineers. His election to the Iron and Steel Institute took place as long ago as 1889. He died at New Orleans, Louisiana, on October 22nd, 1912, at the age of 56.

M.E.R.L. Research Summaries

THE Mechanical Engineering Research Laboratory, D.S.I.R., is preparing short summaries of the results of recent research of direct industrial interest to help firms to keep in touch with its work. They will give straightforward accounts of work still in progress at M.E.R.L. as well as the main findings of completed investigations. They are intended for circulation to senior management as well as to design and production staff. Among subjects covered from time to time will be: fatigue and creep of engineering materials and components; bearings, lubrication and wear; performance of gears and other mechanisms; engineering metrology; noise control; design and performance of hydraulic machinery; heat transfer and applied thermodynamics; and machining, extrusion and other metalworking processes. Engineers and industrial organizations who would like to receive copies of M.E.R.L. Research Summaries are invited to send their names to: The Director, Mechanical Engineering Research Laboratory, East Kilbride, Glasgow.

National Science Lending Library

THE Department of Scientific and Industrial Research will take over part of the former Royal Ordnance Factory at Thorp Arch, near Boston Spa, Yorks, for the use of the new National Lending Library for Science and Technology. Present proposals indicate that the library will begin operating at Thorp Arch in 1961, and become fully operational during the following year. Existing large single-storey buildings will be converted into offices and book-stores, and the site provides adequate room for expansion in the future.

The new library—the nucleus of which already exists in the D.S.I.R. Lending Library Unit now at Chester Terrace, Regents Park, London—will cover all subjects in science and technology, except for some fields of medicine. It will take over the responsibility for the lending service now provided by the Science Museum Library, which in future will concentrate on serving the needs of the enlarged Imperial College of Science and Technology. It is also taking over some of the literature now held by the Science Museum Library.

The present Lending Library Unit has been collecting literature for the National Library since 1957. It already operates a loan service for Russian literature, which is being progressively extended to cover publications from other countries. Eventually, much of the scientific and technological literature in the world will be included in this collection, to make it the most comprehensive of its kind in the United Kingdom.

The new library in Yorkshire will make its unique collection available to research, industrial, educational and other organisations by loans and photographic reproduction. Its primary objective will be to encourage the greater use of scientific and technical literature. One important activity will be the expansion of work on the translation of Russian scientific literature, now organised by the Lending Library Unit in collaboration with the National Science Foundation in the United States.

I.C.I. Nuclear Piping Contract

I.C.I. (BELGIUM) S.A., as agents for Marston Excelsior, Ltd., Wolverhampton, have obtained an order worth just over £100,000 for aluminium piping in connection with the experimental water-cooled reactor BR.2 now in course of erection at the nuclear research centre at Mol in North Belgium for Centre d'Etudes Nucleaires. Both firms are subsidiaries of Imperial Chemical Industries, Ltd. This is believed to be the first large order related to nuclear energy to be obtained by a British firm in Belgium, and is also the first such order to be placed with I.C.I. by a nuclear organisation outside the United Kingdom. It comprises piping and fittings in aluminium alloy, up to 30 in. diameter, to connect the reactor shell to the heat exchangers and the exchangers to the cooling pond.

BR.2 is an advanced type of Materials and Engineering Test Reactor, using uranium enriched to 90% U235 as fuel, with metallic beryllium as the moderator. At full output of 50MW, the epithermal flux will be $2{\cdot}4 \times 10^{15}$ neutrons/sq. cm./sec. and the thermal flux $6{\cdot}2 \times 10^{14}$. Criticality will be obtained with approximately 4 kg. of fuel. Heat will not be recovered, but will be removed from the reactor by demineralised natural (not heavy) water circulated at 2270 cu. m./hr.

Marston Excelsior, Ltd., are specialists in the fabrication of aluminium alloy and are experienced in this class of work for nuclear energy purposes. They will supply the pipes and fittings and carry out all the site welding at Mol, as well as supervising erection by the Belgian firm Fabricom.

Automatic Manufacture of Bearings

Timken Roller Bearings' Bucyrus Plant

A general view of the cone finishing department shows the small number of men needed to attend the machines on the five cone lines.

IMMEDIATELY following the end of World War II, the Timken Roller Bearing Company began to explore the possibilities of a straight-line method of producing bearings. Costs had to be lowered, speed of production increased, and the quality of the product improved. Quality had to be systematically standardized, so that each bearing part produced would be of equal quality and precision. The excellent results of this careful planning were revealed when details of the company's Bucyrus plant were made public. Thirty-three million cups and twenty-seven million cones can be produced each year at Bucyrus. Floor space at the plant measures 180,000 sq. ft., and the plant site totals 87 acres of land situated between the Pennsylvania Railroad and U.S. Route 30. Total investment in plant and machines is about 12½ million dollars.

All the screw machines and most of the other equipment had to be of special design or have special adaptations to fulfill the requirements imposed by this type of plant. Emphasis was placed where possible on smaller machines, since the range of work performed by them was much less than their conventional counterparts. The smaller single purpose screw machines and grinding machines made possible great savings in plant production space. Cost of each production line is estimated to be in excess of 1 million dollars.

Costs at Bucyrus vary inversely with production; as the volume of production goes up, the cost of bearings comes down. For example, a set of Timken bearings for low and medium priced 1957 cars costs less today than in 1953, despite spiralling costs of both labour and materials. These economies are possible because of new light weight, high capacity bearings, a high degree of standardization of bearings for automotive applications, and a high rate of efficient production. Thirty-four different cup sizes are at present produced, but a total of fourteen cups and cones constitute 80% of the production volume. It is hoped that with further or increased standardization of application the production requirement will be reduced to twelve to fourteen sizes. With the increased standardization requiring commensurately fewer line changes such further economies are probable.

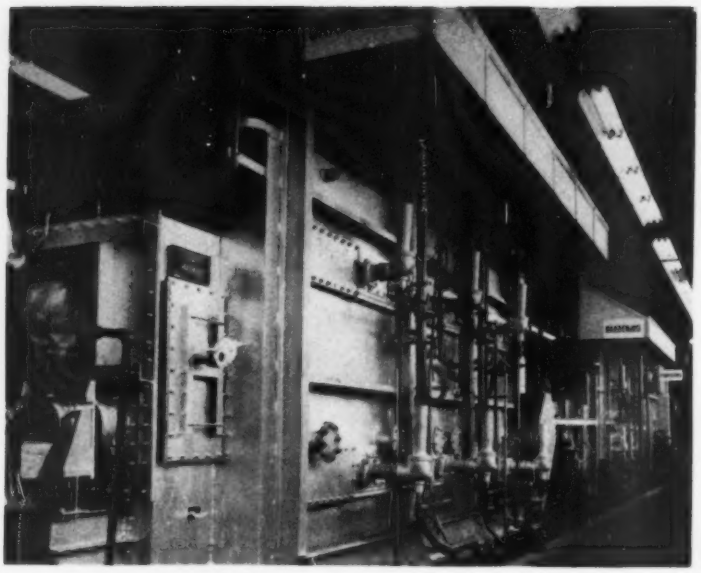
The cup and cone lines are almost completely automatic in operation. From the time a load of tubes is placed on the screw machine stock rack until the finished and wrapped product is placed in the dispatch case, all operations, including final gauging, are handled automatically. The parts move from one operation to another by conveyor or chute. With the system previously used in comparison, an 09000 cup travelled a total of 11,370 ft., had 89 separate handlings, received 30 separate actual working operations and was touched by 100 different handlers or operators.

On critical operations, bearing parts leaving the machines are held in chutes until roving inspectors check the last piece in the chute. If the part is within tolerance the balance in the chute is released and conveyed to the next operation. Since the period between operations is relatively short, it is quite easy to make effective changes if something is wrong. For instance, at the internal honing operation, if the ground finish is too rough and parts do not clean up in honing, a change can be made at the grinding machines to correct the condition immediately.

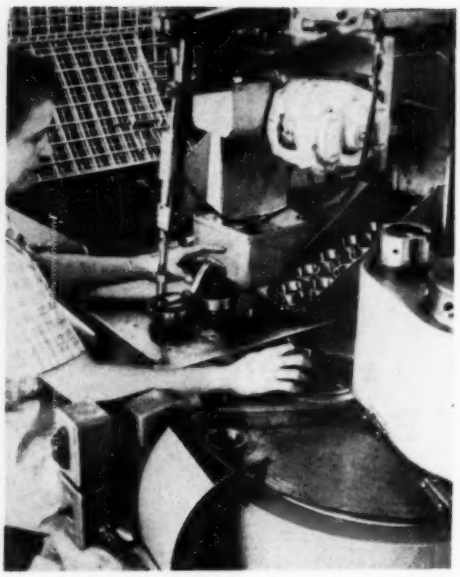
Product Banking System

To provide a steady flow of material through all operations at predetermined average rates a product banking system was integrated into the production line. Each machine is integrated with and interdependent upon machines preceding it in the production sequence. An interlock system provides a steady flow of product at carefully predetermined rates. No machine or group of machines, therefore, gets either too much or too little product at one time.

Because it is not economically feasible to start up and shut down heat-treatment plant, the heat-treatment facilities are geared to handle in seven days the volume



Cups and cones are processed through carburizing, hardening and tempering furnaces during heat treating.



Close-up of the operator on the cone assembly operation. A magnetic elevator brings rollers into the feeder tubes that place them into the cage. The assembly is put into the closing-in press on the right, and the finished cone assembly ejected into a conveyor. An electric eye beam, broken by the operator's hand, sets and trips the press. Operators can complete as many as 1,200 cone assemblies in an hour.

of products processed by other departments in five days. To this end Timken engineers devised the product bank system, incorporating product storage or banking, by means of which a steady feed of product from one operation to another is possible. Two days' storage capacity of cups and cones between green machining and heat treating, and also between heat treating and grinding, is provided for in bulk storage bins. Smaller bulk storage bins are located between the screw machines and stamping and chamfering operations. This banking system provides storage for products from the screw machines during periods of tool change or maintenance on these single operation machines. Bulk storage required the development of feeding and orienting devices to enable the product in a single line to be properly positioned for the next operation.

Another vital link in the product banking system are the distributing conveyors in the finishing departments, which feed races directly into the grinding and honing machines. Bearing parts move in a continuous circle above and ahead of the machines, making all parts in the reserve immediately available to all operating machines. As an opening in a machine chute occurs, a bearing part ready for processing drops into place in the chute. The distributor conveyor was designed and developed by Timken engineers.

The interlock system, which operates by means of a series of limit switches and photo-electric cells, stops machine operation where the machine has run out of product for processing, when the machine itself is malfunctioning, or when product is being processed too fast for a subsequent operation in the line.

The innovations and new approaches to solving problems necessary in putting a plant like Bucyrus into operation are innumerable. Listed below are those engineering accomplishments that perhaps merit particular attention.

Hot-Rolled Tube Stock

Early in the design of the screw machines the question of using hot-rolled or cold-finished tubes was carefully considered. The advantage in using hot-rolled tubing is that the cold finishing operation costs about two to four dollars extra per tube, depending on the size. However, the hot-rolled tubes, as rolled, may vary tube to tube in outside diameter by as much as 0·060 in. in the larger Bucyrus sizes. Conventionally, when hot-rolled tubes are chucked in the spindle, the collet tension must be adjusted. Otherwise, a minimum size tube might slip during the machining operation and a maximum tube might be chucked so tightly that damage to the collet or other machine parts could result.

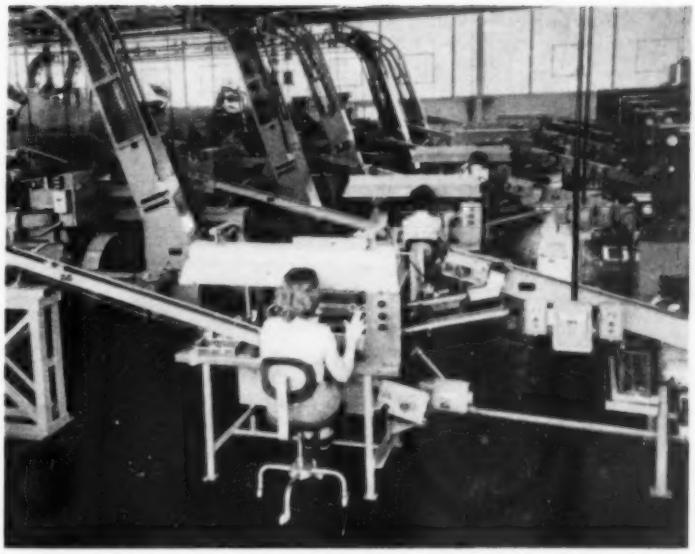
Hand chucking of individual tubes did not fit in with the Bucyrus concept of completely automatic operation. It was known that Belleville springs (dished washers) could be designed to have nearly flat load-deflection curves over a considerable range of deflection. All three suppliers of Bucyrus screw machines cooperated with the company in working out chucking devices incorporating properly proportioned Belleville springs so that in every size of machine an almost constant chucking pressure is obtained over the full range of hot-rolled tube tolerances. Timken is probably the only company in the world which can use hot-rolled tube stock, automatically load the tubes into the machines, and start the machines under power with no hand chucking or collet adjustment—tube to tube.

The stock racks which feed the screw machines in the green machining department are of special Timken design. Loaded by a fork-truck or crane, the stock rack holds about an eight-hours' supply of tubing. Tubing is

positioned in the screw machines from the stock rack automatically. When out of stock, the machine stops, with loading ram retracted and the collet open. The attendant merely removes the butt end, and by simply pressing the handle of an air valve, the loading cradle is opened, a new piece of stock rolls into the cradle, the cradle closes and a ram pushes the tubing into the spindle until it hits the stock stop. The tubing is automatically chucked and the machine resumes operation. This procedure is carried out in seconds.

Provision has also been made for tool adjustment in the holders to make the tool assemblies interchangeable. The carbide tooling is pre-ground and pre-set in tool holders, and made ready for immediate installation on all screw machines at scheduled intervals. The advantages in pre-setting all cutting tools to reduce machine down-time were apparent. To accomplish this, all screw machines were designed with double adjustments. In addition to the adjustments provided in the tool holders, the slides are adjustable to obtain size on a new part being set up. Thereafter, tools are changed with no further machine adjustment. By pre-grinding and pre-setting the carbide tools, down-time for tool changes is practically eliminated.

Improvement in the cutting off of tubing with carbide tools had to be worked out before automatic single spindles could be economically operated. This was accomplished by using two cut-off tools working simultaneously, the first narrow tool cutting a single wide chip, the second, a wider tool, cutting two narrow chips. A free flow of the cut-off chips out of the cut-off slot is thus possible. This tool arrangement prevents wedging of hot, expanded chips against the sides of the slot. Chip jamming in the slot formerly caused much serious tool damage.

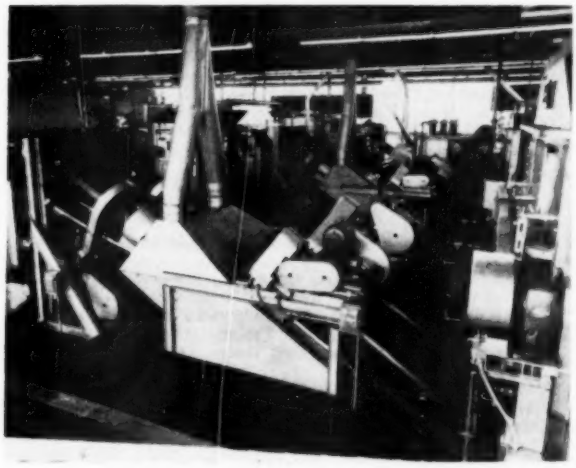


Six automatic gauges, visual inspection tables and cone assemblies handle the production of the five cone lines.

Another device designed especially for the single spindle screw machines by Timken engineers was a unique hydraulic system which resulted in an increase in productivity of the single spindles by as much as 30%.

Four slides operate off the screw machine cam shaft; the end working slide which carries boring and turning tools; the forming slide which carries two radius tools; the breakdown slide which carries the breakdown tool; and the cut-off slide which carries the cut-off tool. All these tools work simultaneously until just a few seconds before the cut-off tool completes the cutting cycle. Before the cut-off occurs, a separate hydraulic system makes possible the quick removal of the end working tool slide and its re-engagement to the camming at the next cycle. As much as one-third of the cycle time was formerly used in returning the end working slide to the start of the new cycle.

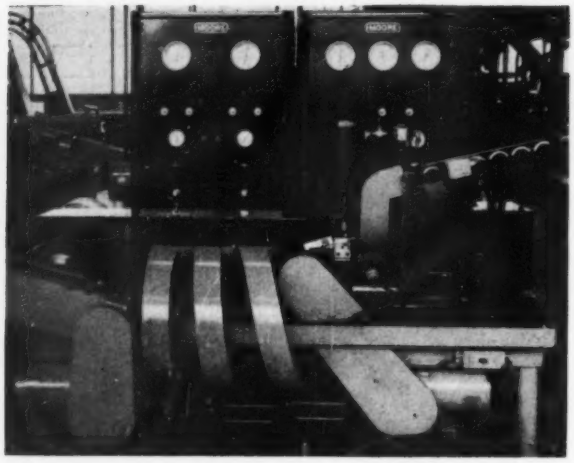
The system of handling coolants and of disposing of chips from the green machining department was also designed by the company's engineers, and is unique in the metal processing industry. A hole in the machine base directly beneath the spindle permits coolant and chips to fall directly into a sluiceway. Chips and coolant are separated, with the coolant recirculated into the coolant system, while the chips are automatically conveyed by means of a series of spiral and shaker conveyors to large trucks, returned to the Canton Steel Mill and remelted.



A cross view of the centre of the cone heat-treating department shows the washers and the double spiral conveyors leading to the hardening furnaces. The area under the iron latticed floor houses the oil filter and refrigerator units and quenching tanks.

Heat-Treatment Facilities

In order to carry out the Bucyrus concept of through-flow, it was necessary to develop entirely new heat-treatment equipment and methods. This work was carried out in conjunction with Surface Combustion Corporation of Toledo, Ohio. A spiral retort carburizing furnace was first developed using a carburizing atmosphere of endothermic gas and natural gas maintained in the retort at a slightly positive pressure. The carburizing temperature is 1,700° F. (925° C.), and the time cycle from 5½ to 8 hours, with a resultant case depth



The Moore automatic gauge simultaneously measures the cone's overall length, O.D., raceway stand, taper, rib length and bore. The gauge can inspect 42 cones a minute.

of approximately 0·025–0·040 in., as required. A maximum surface carbon of 1%, graduating down progressively to the core carbon of approximately 0·20% is obtained.

The parts pass from the furnace into a sealed oil quench, and are automatically picked up by another spiral conveyor and carried through a washer to remove excess oil and then mechanically fed into a re-heat furnace for case refinement. There are two types of re-heat furnace. For smaller parts that do not distort excessively, another spiral retort of smaller dimensions was designed, and for the larger parts that tend to distort more, a continuous pusher furnace was developed with an automatic plug quench. In this case, the quenching machine was of completely new design. The re-heat furnaces have endothermic gas atmosphere and operate at 1,510° F. (820° C.). From the re-heat furnaces the parts are carried through a washer for a final tempering at 350° F. (175° C.).

Grinding Operations

Improved methods of grinding and closer control have made it unnecessary to match cone and roll sizes. Grinding dimensions are held so closely that any cone can be assembled with standard size rolls, thus eliminating the need for selective assembly. Two types of rib grinding machines are used. One is designed by Timken and incorporates a magnetic work driver, work supporting shoes, and a hollow or cupper grinding wheel. The second is a conventional Cincinnati Microcentric.

The loading mechanism on the Nos. 2 and 3 Cincinnati Centreless grinders is another noteworthy accomplishment. Cups fall into the loader from a gravity chute, each stroke of the loading mechanism placing cups in a horizontal column. Pressure is applied by a system of weights pushing the column of cups against the grinding wheel. It is important that the pressure is steady and that the cups are fed through squarely. If the cups are not in a tight column, they may fall sideways, resulting in an off-square grind. Too much pressure may cause an irregular finish on the O.D. surface.

New honing machines, using abrasive tape instead of honing stones as a honing medium, have been installed. With these machines the tape is advanced for each cup so that a new and identical abrasive surface is presented to each cup. A high degree of uniformity of finish, better clean-up of grind, and considerably improved control of stand and taper are therefore obtained. Close control is maintained at all finishing operations by means of air gauges capable of a uniformly high degree of accuracy.

Cups and cones leaving the finishing departments are gauged by Moore automatic gauges which simultaneously measure all the critical dimensions. In the case of cones, overall length, outside diameter, taper and rib length; and in the case of cups, it gauges the stand, taper, O.D., and length.

As rapidly as economically feasible, improvements developed for the Bucyrus plant are being incorporated at all the company's other plants. Smaller production quantities place certain limitations on the extent to which this can be done and still provide the same economic advantages. Screw machines of the same design as those at Bucyrus, to machine cups up to 10½ in. in diameter, have been placed in operation at the Canton, Columbus, and St. Thomas plants.

Library Publications Available

"Advertising and Market Research" is the title of a pamphlet showing the resources of the Manchester Commercial Library on these subjects in the form of periodicals, statistical data, dictionaries, directories, annuals, readership surveys, consumer reports, marketing surveys and text books. The list is selective and should prove most useful both to advertising executives and their clients. Numbers 8 and 9 in the Library's European Economic Co-operation series of reading lists are also now available. Copies of these publications can be obtained from the Commercial Library, Central Library, Manchester, 2.

New Years Honours

(*Continued from page* 40)

B.E.M.

G. W. Ashman, Outside Supervisor, B. Whitehouse and Sons, Ltd.
J. Ballantyne, Chief Inspector, Fawcett, Preston and Co., Ltd.
S. Couch, Head Foreman Coppersmith, Vickers-Armstrongs (Shipbuilders), Ltd.
J. Forster, Leading Hand Fitter, Alkali Division, Imperial Chemical Industries, Ltd.
J. Grundy, Grinder, Joseph Lucas (Electrical), Ltd.
R. Hilditch, Head Foreman Shipwright, Harland and Wolff, Ltd.
A. H. Hunt, General Foreman, British Thomson Houston Co., Ltd.
A. V. Lush, Chief Warder, Geological Survey and Museum, Department of Scientific and Industrial Research.
W. McKay, Forman Tester, Drysdale and Co., Ltd.
F. J. Mankelow, Office Keeper, Patent Office, Board of Trade.
C. Meikle, Electrical Instrument Tester, The Record Electrical Co., Ltd.
G. W. Nicholson, Valve Shop Foreman, Richardsons Westgarth (Hartlepool), Ltd.
L. Owen, Toolroom Fitter, Blackburn and General Aircraft, Ltd.
J. Plunkett, Sample Passer, Dorman Long and Co., Ltd.
Mrs. H. Salter, Winding Supervisor, Rotax, Ltd.
F. Shaw, Assistant Foreman, Outside Engineering Department, Cammell Laird and Co., Ltd.
H. Smallbones, Machine Shop Inspector, Taskers of Andover (1932), Ltd.
W. Thackray, Hardener, George Ibberson and Co.
A. J. Withey, Tool Designer, J. W. Singer and Sons, Ltd.

Growth of Sintered Metal Compacts

By J. E. Elliott, B.Sc., A.I.M.

Bound Brook Bearings, Ltd.

In contrast to the shrinkage which occurs on sintering pure metal powders, a growth effect is sometimes observed on subjecting mixtures of metal powders to a sintering treatment. The results are presented of a study of growth on sintering iron-copper and copper-tin mixtures, which takes into account the effect of such factors as powder characteristics, additions to the mixture, compact density and sintering conditions.

A FREE surface represents a condition of instability due to the unsatisfied bonds of surface atoms, and this unstable condition is the basic driving force of surface tension, whereby all materials tend to reduce their surface area. Metal powder can be distinguished from massive metal, in that it is characterised by a large surface area per unit volume ; the finer the powder the greater is the surface area. It is not surprising, therefore, that metal powder compacts should shrink when they are sintered, since this represents a reduction in the surface area. The elevation of the temperature during sintering allows the surface tension forces to become increasingly active, and it is normal for a higher degree of shrinkage to develop at higher sintering temperatures. It is also generally observed that the finest powders shrink most, presumably due to the higher surface tensional forces which are associated with the greater surface area.

It is universally true that all pure metal powder compacts shrink when sintered. It is also true that alloy powders generally exhibit the shrinkage phenomenon, and this also applies to many mixtures of elemental metal powders in which alloying and sintering proceed together during the sintering operation. However, not all metal powder mixtures persistently shrink, and a growth effect can be observed at some stage during the sintering of certain mixtures. The growth effect is associated with some of those powder mixtures in which one of the constituents becomes molten during the sintering operation and "liquid phase" sintering develops. Two outstanding examples from industrial powder metallurgical practice are mixtures of iron and copper and copper and tin powders, which are widely used in the respective manufacture of iron and bronze self-lubricating bearings and sintered components.

The incidence of growth during sintering appears to be contrary to the general ideas associating reduction in area with shrinkage. For this reason alone it merits interest and study, but in addition, growth is of considerable practical importance to those engaged in the manufacture of sintered materials which exhibit the phenomenon.

The growth effect has been noted over a period of years by a number of workers, but the subject has generally been dealt with in conjunction with other aspects of sintered materials. The current aim is to present further and particular evidence of growth effects only in powder compacts, and to discuss their significance and interpretation. The information to be presented has been drawn primarily from the two types of powder mixtures already mentioned, i.e. the iron-copper and the copper-tin combinations, and will be dealt with in that order.

IRON-COPPER MIXES

It has been mentioned that iron-copper powder materials are employed in the powder metallurgy industry for the manufacture of sintered bearings and components. Production of this class of material is based upon the availability of relatively cheap iron powder, which allows a basically low cost article to be manufactured. However, components formed from iron powders alone and sintered in furnaces which are based upon nickel-chromium elements, have limited properties, particularly with regard to strength. This is due to the sintering temperature being limited to a maximum of, say, 1,150° C. in such equipment.

Copper additions are probably the most widely adopted means of improving the properties of sintered iron compacts, and their use is primarily due to the marked improvement in strength which is achieved with quite small additions of the element, together with the relative ease and cheapness with which the compacts can be manufactured. The sintering operations can be satisfactorily carried out at temperatures above the melting point of copper, i.e. 1,083° C., but below the normal maximum of 1,150° C. for furnaces with nickel-chromium elements. Under these liquid-phase conditions, the development of mechanical strength is rapid and the sintering treatment need only extend for a matter of minutes. The sintering cycle can be satisfactorily carried out in mesh belt continuous furnaces at high rates of production, using atmospheres such as exothermic gas.

Iron-Copper Alloys

The iron-copper binary alloy diagram, Fig. 1, indicates that there is only limited solubility of copper in iron. Under equilibrium conditions, *alpha*-iron can hold virtually no copper in solution at low temperatures, but the solubility of copper in *gamma*-iron is substantially greater. At the *alpha-gamma* transformation temperature, 5% can be absorbed, and at 1,094° C., the melting point of the *alpha*-copper-iron alloy, approximately 8% of copper can be held in solution. For practical purposes, therefore, the limit of solubility of copper in *gamma*-iron under production sintering conditions is of the latter order. Any copper in excess of the 8% level will remain as free *alpha*-copper-iron.

The mechanical properties of the iron-copper alloys[1] indicate that copper enhances the strength of iron up to about the 10% copper level, and iron-copper powder

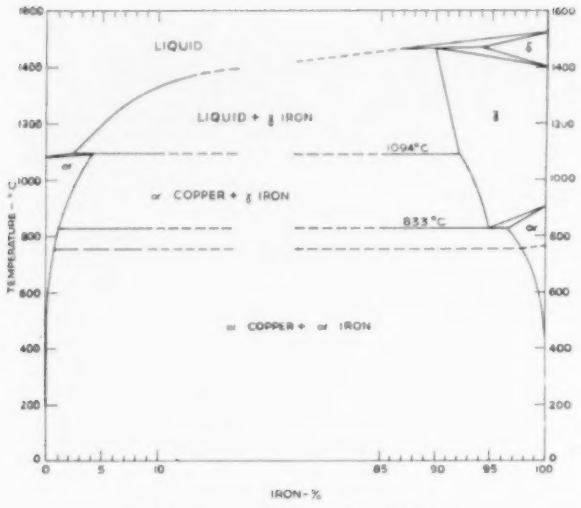


Fig. 1.—Iron-copper alloy diagram.

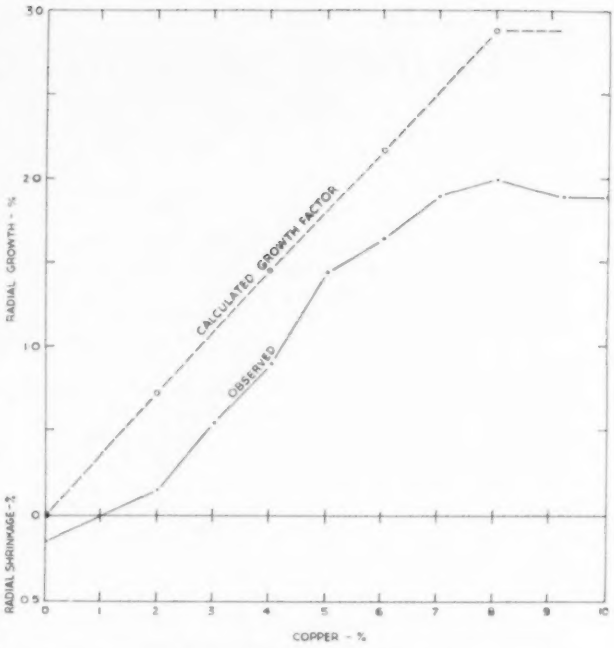


Fig. 2.—Copper additions versus growth (iron-copper). Sintering temperature, 1,150° C.

mixtures for the manufacture of bearings and components generally lie within this alloy range. Under the liquid phase conditions which operate at temperatures in excess of 1,094° C., alloying rapidly develops according to the limits imposed by the diagram. Upon cooling, equilibrium conditions are seldom achieved under manufacturing conditions, and substantial amounts of copper are retained in super-saturated solution unless the rates of cooling are extremely low. This phenomenon can give rise to various heat-treatment effects which additionally influence the mechanical properties.[2]

Growth of Iron-Copper Mixes

Fig. 2 shows the typical influence of copper additions upon the growth of iron powder compacts. The particular powders used in this case were Swedish sponge iron powder, grade MH100, and — 100 mesh electrolytic copper powder, which were compacted to give a green density of 5·8 g./cc. and sintered at 1,150° C., using exothermic gas in a conveyor furnace. The time at sintering temperature was of the order of 15 minutes. The linear growth in the three dimensions was generally similar and radial growth has been plotted.

It will be observed that the iron powder alone shows a slight shrinkage of 0·15% and that growth increases with copper up to the 8% level. Thereafter, the growth decreases slightly beyond the peak at 8% copper. The peak growth thus occurs at the same copper level as is indicated by the alloy diagram to be the limit of solubility at the sintering temperature employed.

Mechanism of Growth

The evidence suggests a connection between growth and alloying effects, and a study of the structure of unsintered and sintered compacts throws some light upon the point. Figs. 3 and 4 are photomicrographs of green and sintered compacts, respectively, comprising 10% of — 100 mesh electrolytic copper mixed with MH100 Swedish iron powder and prepared according to the conditions previously outlined.

The green compact shows quite clearly the fairly large copper particles which are present. The structure of the sintered compact is interesting for the form of the porosity; this is characterised by a few fairly large pores, together with a considerable number of relatively fine ones. Comparison of the two structures indicates that the distribution of the few large pores of the sintered compact is to be related to the distribution of the relatively few, but large, copper particles of the green compact. This suggests that during sintering the copper particles have completely melted and have migrated from their original locations. A new pore distribution has, therefore, been created in the sintered compact by the movement of the copper.

The density of iron is 7·86 g./cc., and it is reported[1] that the density of iron-copper alloys is not significantly different. One particular measurement by the author of the density of a 4% copper alloy gave a value of 7·865 g./cc. It must be concluded, therefore, that alloying in itself is no basic reason for any significant change in volume, and it would appear that the explanation of the growth effect must be sought in the movement of copper which occurs in the compact during the sintering cycle.

From the evidence available it is possible to develop a simple picture of growth as it probably occurs in an iron-copper compact, and Figs. *5a*, *b* and *c* schematically depict the conditions which might arise in the green, initial liquid-phase, and fully-sintered conditions, respectively. Fig. *5a* indicates the discrete nature of the copper and iron powder particles in the green compact. When liquid copper first forms during sintering, it is drawn by surface tension forces over the iron particle surfaces to the junctions of the iron particles, as shown in Fig. *5b*, and migration of copper, therefore, takes place during this phase of the sintering. No doubt the copper, in the course of fusion, can rapidly absorb iron up to the normal solubility limit of about 2·5%.

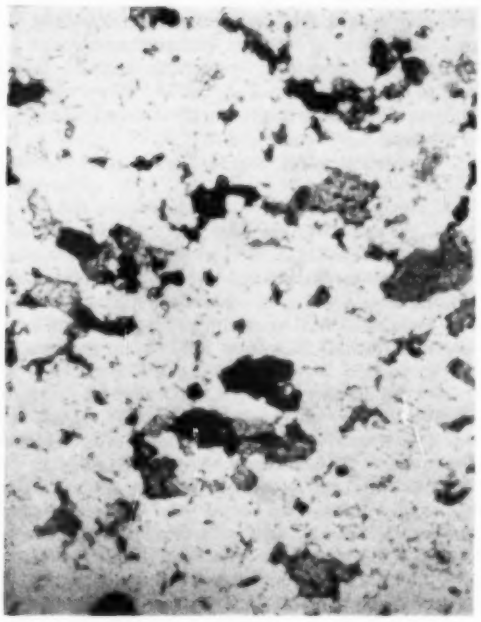


Fig. 3.—Photomicrograph of green compact. ×100.

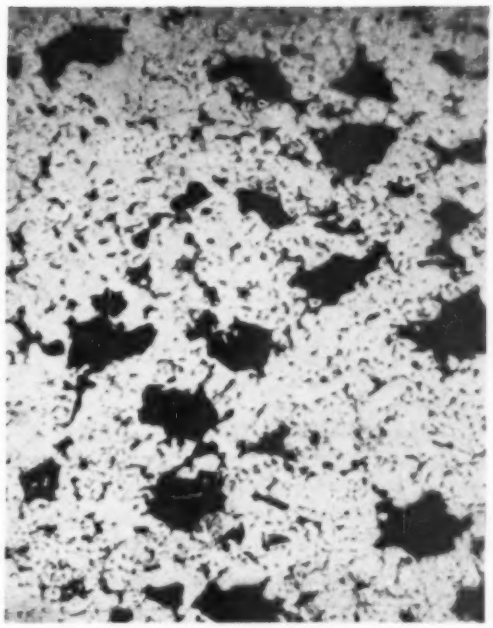


Fig. 4.—Photomicrograph of sintered compact. ×100.

During the main cycle of the sintering operation, alloying of the copper and iron proceeds via those regions of mutual contact which then exist, i.e. primarily in the regions of the iron particle junctions. Since the density of the alloy is virtually identical with that of the iron, a proportional increase in the volume of metal in the junction regions must develop as the copper is absorbed into solution in the iron. The net result is as shown by Fig. 5*c*, and the resultant movement of the iron particles away from one another can be interpreted as a three dimensional growth effect.

In considering the increase in the volume of iron as a result of alloying, it should be noted that diffusion is in one direction only, i.e. copper can enter the iron, but not *vice versa*, since the copper is already saturated. A further factor which may operate is the mass transfer of iron to the weld areas by a process of solution and deposition via the molten copper. Iron could be dissolved in the vicinity of the solid copper particles and deposited during absorption of the copper in the areas of the iron particle junctions.

It will be clear that, whilst new pore space has been created by the migration of the copper, the overall surface area of the compact has been reduced by that amount contributed by the copper powder. This is undoubtedly an over simple view of the actual surface area changes which take place in the compact, since no account is taken of the surface area changes of the iron particles themselves, but it is highly probable that the basic thermodynamic condition of a reduction in surface area is achieved during sintering, despite the growth of the external dimensions. Some actual measurements of the surface area changes would be of interest.

Shrinkage and Growth Factors

A recent American paper by Gummeson and Foss[3] upon the effect of copper powder additions to iron powder has discussed, among other aspects, the dimensional changes which occur in such mixtures, and represents, perhaps, the fullest treatment of this aspect to date. The authors suggest that a useful approach to the question of dimensional change can be based upon the idea of separate factors for shrinkage and growth. Thus, it is suggested that the overall dimensional change which is observed is essentially a combination of individual shrinkage and growth effects. Whichever factor is the greater will determine whether a shrinkage or growth effect prevails.

When considered in this way, the dimensional changes in iron-copper mixtures need be separated into those causing shrinkage and those causing growth. It is quite clear that the shrinkage effects must be associated with the iron, since it forms the base structure of the compacts and, being an elemental metal, inherently tends to shrink. In the graph of Fig. 2 it will be noted that the shrinkage factor for pure iron is 0·15%. It would be unwise to assume that the shrinkage factor for the iron-copper alloy structure is necessarily 0·15% also, and possible influences of the alloying element upon the shrinkage characteristics of the iron must be considered. In this particular instance it is unlikely that the shrinkage factor of the iron-copper structure is very different from

(a) (b) (c)

(a) Green compact. (b) Initial liquid phase. (c) Full sinter.

Fig. 5.—Mechanism of growth (iron-copper).

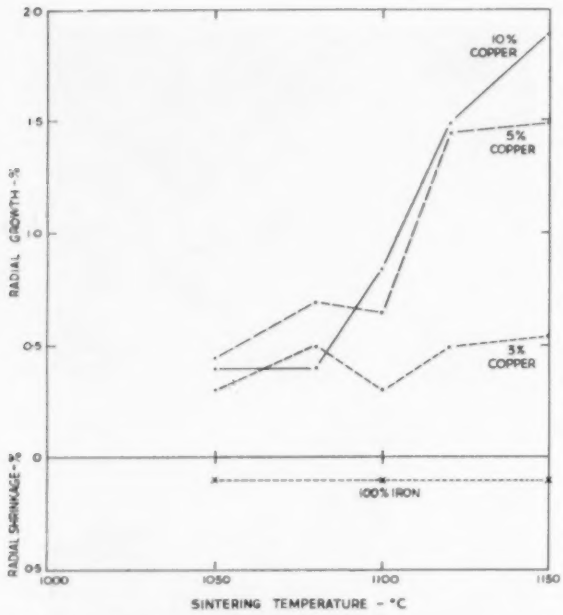


Fig. 6.—Sintering temperature versus growth (iron-copper). Sintering time, 15 minutes.

that of iron, since the sintering temperature as a proportion of the melting point is also low, and shrinkage effects are not likely to be great. It may be that shrinkage will be less owing to the establishment of an alloy pore structure, characterised by relatively broad inter-particle welds, which is more resistant to shrinkage than the original iron structure.

On the other hand, the growth effect is connected with the alloying of copper with the iron, and it is, therefore, reasonable to associate the growth factor with the copper addition. Indeed, Gummeson and Foss have actually given the title "copper growth" to the factor. It follows from the suggested mechanism of growth that the amount of growth depends upon the amount of copper which alloys with the iron; it is, therefore, to be expected that growth will increase with copper content and will reach a maximum at the limit of solubility of copper in iron. Fig. 2 demonstrates that this is so, and that the peak growth coincides with the 8% limit of solubility applicable to the sintering temperature.

Fig. 2 also indicates that above 8% copper the overall growth decreases slightly. Since the growth factor itself is at a maximum at 8% of copper and above, it would appear that the shrinkage factor must have increased, thereby reducing the overall growth. It is possible that the increased shrinkage factor above the 8% copper level may be due to the lower effective density of the iron structure, following from the dilution effect of the extra copper present. It is well established, of course, that shrinkage is generally greater with lower density compacts. Alternatively, the presence of the free copper may in itself alter the shrinkage characteristics of the alloy structure.

Calculated Growth Factors

On the assumption that the growth effects in iron-copper mixes are due to alloying effects which primarily emanate from the regions of the iron particle junctions, it is possible to calculate a simple form of growth factor. Since no significant density changes are involved in the solution of copper in iron, it follows that if, say, 8·7% by weight of copper (i.e. enough to achieve the 92/8 iron-copper ratio) is absorbed, an 8·7% volume change will follow. The uniform linear growth equivalent to this three dimensional change is 2·9%.

This calculated value, together with others, is set out in Table I and inserted in Fig. 2. It is apparent from Fig. 2 that the calculated values lie above the observed values of growth. Whilst this point will be further discussed in a later section, it is as well to appreciate that the calculation assumes that all the copper alloys with the iron in those regions which are most likely to produce growth, i.e. in the iron particle junctions, and the calculated values should, therefore, tend to be maxima rather than otherwise.

It must be emphasised that the calculated values are based upon very simple assumptions, and are to be regarded as a guide only to the likely order of growth. For instance, no estimate of shrinkage factor has been made, and another possible aid to growth already mentioned, i.e. mass transfer of iron, has not been taken into account. The maximum volume change associated with this latter factor is, however, likely to be small, since 8·7% of copper can dissolve approximately 2·5% iron, i.e. a transfer of 0·22% iron is possible. This compares with the potential 8·7% volume change due to absorption of copper in the iron.

Influence of Sintering Temperature upon Growth

Consideration so far of the ways in which the alloying of copper and iron proceeds has assumed that the sintering conditions quoted are adequate to promote both fusion and alloying of the copper, with consequent effects upon dimensional change. With sintering times of the order of 15 minutes at a sintering temperature of 1,150° C., fusion of the copper was complete, and alloying appeared to have proceeded to a substantial degree.

It will be appreciated that growth depends not so much upon the amount of copper which is actually present in the compact, but upon the amount of copper which is allowed to alloy with the iron. Since the degree of alloying must depend upon the sintering conditions, particularly time and temperature, it is of interest to consider the relationship which exists between, say, sintering temperature and growth. Fig. 6 shows the trend of growth with temperature over a range likely to be employed in furnaces with nickel-chromium elements. The compacts were as previously described.

It will be noted that iron alone consistently shrinks by 0·2% over the whole temperature range, and that up to 1,080° C. all the copper mixes grow about 0·5%. Above 1,080° C., the 5% and 10% mixes grow substantially more than 0·5%, whilst the 3% material growth remains at this level. Similarly, the 5% mix maintains a growth of about 1·5% above 1,120° C., whilst the 10% mix grows to about 2·0% at 1,150° C.

It is apparent that the normal trend of increased growth with increasing copper content applies only

TABLE I.—EFFECT OF COPPER CONTENT ON GROWTH (CALCULATED)

Copper (%)	Volume Change (%)	Linear Growth (%)
2	2·2	0·73
4	4·35	1·45
6	6·5	2·17
8	8·7	2·90

under those conditions which allow maximum alloying to take place, i.e. at 1,150° C. At temperatures below this level, the determining factor is the temperature itself, and not the amount of copper which is present. Thus, in the range 1,050°–1,080° C., there occurs only sufficient alloying of copper to produce about 0·5% growth, whilst at 1,120° C. the amount of alloying which is permitted can produce a growth of about 1·5% and no more.

Fig. 6 indicates that growths substantially in excess of 0·5% develop in the 5% and 10% mixes only at temperatures above 1,080° C. Undoubtedly, this is associated with the rapid development of alloying in this temperature range and coincides with the complete fusion of *alpha* copper-iron at 1,094° C. The rates of diffusion of copper in iron no doubt increase with temperature, but the main factor in the rapid increase in growth above 1,080° C. is, without doubt, the development of better contact between the iron and the then liquid copper. Whilst the copper remains solid, the area of contact with the iron is necessarily limited.

It is of interest to note that if sintering temperatures in excess of 1,150° C. are employed, e.g. 1,300° C., it is quite normal to observe shrinkage for even the highest copper-iron mix. The significant factor in this case is that the shrinkage becomes substantial at the higher temperatures and thereby more than offsets the growth factor.

Rate of Heating and Pre-Sintering

Sintering experience shows that the rate of heating of compacts determines, to some degree, the amount of the growth. For instance, if all other things are constant, e.g. belt speed and main zone temperatures, then the growth can change according to the choice of the pre-heat zone temperature. The lower the pre-heat temperature, the greater is the growth, and the only related factor is the change in the rate of heating of the compact.

A pre-sintering treatment may also influence growth to a substantial degree. The introduction of a pre-sintering treatment, particularly at temperatures below that of the main liquid-phase sintering cycle, normally reduces the final growth which is observed after the full sintering treatment. The typical influence of both rate of heating and pre-sintering upon growth is recorded in Table II. In both cases a 5% copper mix was used with a full sintering temperature of 1,120° C. and a sintering time of 15 minutes.

It may be assumed that the basic growth force is associated with alloying, but the form of the alloying of the copper is presumably modified by the rate of

TABLE II.—EFFECT OF RATE OF HEATING AND PRE-SINTERING ON GROWTH

(a) Rate of Heating

Preheat Zone Temperature (° C.)	Radial Growth (%)
800	1·5
1,050	1·3

(b) Pre-Sintering

Treatment	Radial Growth (%)
Full sintering (1,120° C.) only	1·40
Pre-sintering at 1,050° C., plus full sinter	0·95

(a) Green compact. (b) Initial liquid phase.
(c) Full sinter.

(A) Fast heating.

(a) Green compact. (c) Initial liquid phase.
(b) Solid diffusion. (d) Full sinter.

(B) Slow heating or pre-sintering.

Fig. 7.—Effect of rate of heating and pre-sintering on growth (iron-copper). Arrows indicate alloying.

heating or by a pre-sintering treatment. In order to understand how this may arise, it is necessary to consider further the simple picture previously drawn to depict the mechanism of growth. Figs. 7*A* and 7*B* schematically represent the processes which, it is suggested, are involved.

The significance of a slower rate of heating, or the inclusion of a pre-sintering treatment, is considered to be that a certain period of time is spent at elevated temperatures below the melting point of copper. The alloy diagram indicates that a significant degree of alloying can occur between the *alpha/gamma* change temperature at 833° C. and the melting point of copper at 1,083° C. Obviously, the higher the temperature in this range and the longer the time, the more solid diffusion can take place.

It is reasonable to suppose, therefore, that some inter-diffusion will occur across the solid copper particle/iron particle points of contact under slow heating and pre-sintering conditions, and that the iron particle surfaces at these points will tend to grow into the pore space (Fig. 7*B b*). When fusion of the copper occurs, normal migration to the iron particle junctions will arise. However, owing to some of the copper having already diffused into the iron at their original mutual points of solid contact, there will be less copper to migrate and, therefore, less copper to cause growth. The final result is a reduced growth of the external dimensions, which is compensated by a corresponding growth of the iron particle surfaces into the pore spaces originally occupied by the copper (Fig. 7*B c* and *d*). In retrospect, it will be realised that the original schematic representation of growth (Fig. 5) implies a fast rate of heating and, indeed, Figs. 5 and 7*A* are identical.

Comment was made in a previous section that observed values of growth were lower than the simple estimates made by calculation. It was emphasised at the time that the calculated values should tend to be maxima, since it was assumed that all the copper was available for alloying in the regions of the iron particle junctions. It will be appreciated that this assumption is consistent

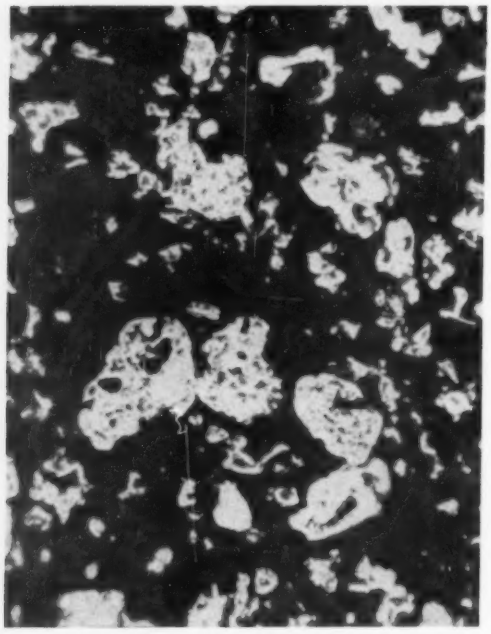


Fig. 8.—Photomicrograph of MH.100 iron powder. ×100.

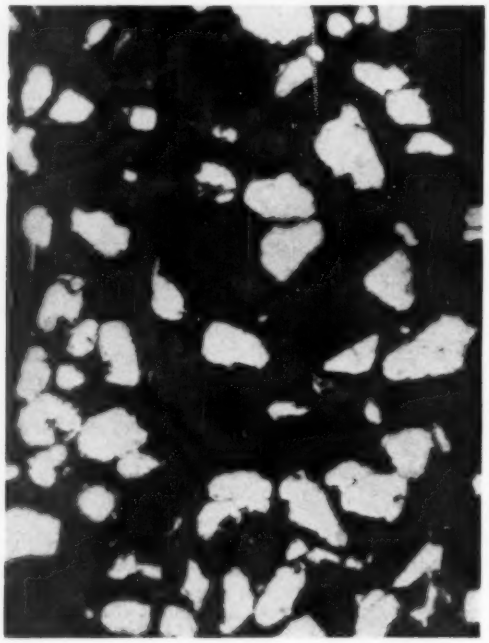


Fig. 9.—Photomicrograph of electrolytic iron powder. ×100.

only with an infinitely fast rate of heating, plus complete absence of any pre-sintering, and may thus help to explain why the observed values of growth are lower than calculated. In practice, the rate of heating is limited to the rate at which heat can be absorbed by the compact, and obviously can never be infinitely high.

Compact Density

The density of the compact is known to influence the growth of iron-copper mixes to some degree, but the variation within the density range of, say, 5·0 to 6·0 g./cc. is relatively small, and has been observed to be no more than 0·1% at a growth level of 1·5% for 5% copper material.

Considered in terms of growth and shrinkage factors, it is apparent that compact density should not influence the growth factor, but could influence shrinkage, since reduced shrinkage is associated with higher densities. General shrinkage effects are small when the sintering temperature is limited to, say, 1,150° C., and it follows that the influence of density upon shrinkage should also be small.

Powder Characteristics

Reference only to mixes based upon Swedish iron sponge powder, grade MH100 (all — 100 mesh), has so far been made. Sponge powders finer than this grade are in use, e.g. MH300 (all — 300 mesh), and they have growth characteristics which are not significantly different from those of the coarser grade. Very slightly lower growth is normally observed, and Table III includes some typical comparative figures on the two powders.

The particle size of the iron powder would most probably influence the shrinkage factor, and a finer iron powder would be expected to show more shrinkage. A decrease in the overall growth is, therefore, logical. The fact that the effect is slight is basically due to the fact that both iron powders show only small shrinkage effects under the temperature and time conditions employed.

It is interesting that different types of iron powder show different growth characteristics, even when the particle size is similar. Electrolytic and Swedish sponge iron powders are examples, and some typical comparative values for growth are also included in Table III.

The electrolytic powder shows slightly more growth than the sponge powder, whilst the iron shrinkage factors are equal. Between these types of powder there exists one basic difference, i.e. particle structure, and the explanation of the difference in growth must presumably be located in this fact. Figs. 8 and 9 are photomicrographs of sponge and electrolytic iron powders, respectively, and the porous and solid structure of the respective powder particles is apparent. To explain differences

TABLE III.—EFFECT OF POWDER CHARACTERISTICS ON GROWTH*

(a) Particle Size Influence

Iron Powder	Radial Iron Shrinkage (%)	Radial Growth (%)
MH.100	0·1	1·45
MH.300	0·2	1·35

(b) Powder Type Influence

Iron Powder	Radial Iron Shrinkage (%)	Radial Growth (%)
MH.100, −100 mesh	0·1	1·45
Electrolytic iron powder, −100 mesh	0·1	1·60

* Compacts contain 5% copper; sintered 15 minutes at 1,120° C.

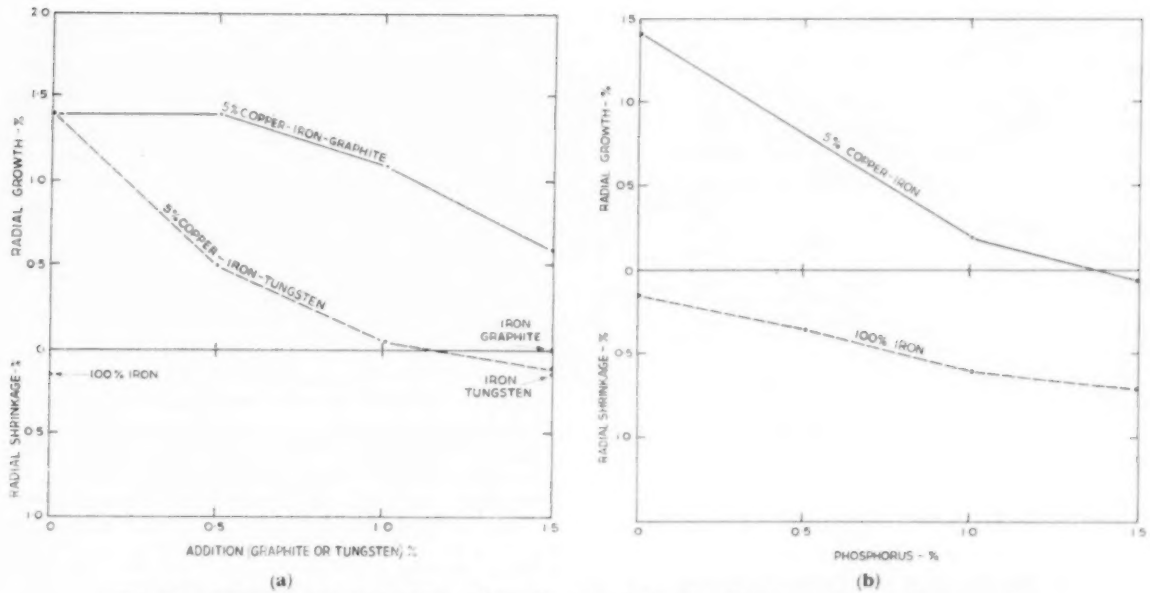


Fig. 10.—Influence of (a) graphite and tungsten, and (b) phosphorus on growth (iron-copper).

in growth arising from the different structures, it is necessary to consider further the mechanism of growth in so far as it may be varied by the particle structure.

Previous considerations have assumed that the iron particles were 100% dense, and that liquid copper was drawn over the iron particle surfaces to the particle junction areas by surface tension forces. In the case of a porous particle, it is to be expected that surface tension will draw copper over all the available iron surfaces and, therefore, copper will migrate into the pores of the particles as well as to the particle junctions. Obviously, less copper will be available in the latter regions and, therefore, less growth may be expected. Thus, a porous or sponge iron particle structure is capable of exhibiting a smaller growth than that based upon an iron powder characterised by solid particles.

Just as the iron powder characteristics determine, to some degree, shrinkage effects, so also do the copper powder characteristics have an effect upon growth. Particle size of the copper powder is one known factor, and finer copper powders are observed to show a slightly lower growth than coarser powders, when mixed with the same iron powder. In the case of mixes based upon MH100 iron powder containing 5% of copper, the difference in growth at the 1·5% level of growth due to using — 100 mesh (152 microns) and — 40 microns copper powder is 0·2%.

Variations in the copper powder can directly influence the growth factor and, in so far as they influence the pore structure of the iron compact, they can have a possible influence upon the shrinkage factor. A fine copper powder will produce a fine pore structure, which will normally possess an inherently greater tendency to shrink, but the stronger influence will probably be that associated with the growth factor. The finer copper powder will have greater contact area with the iron particles, and will thus allow more solid diffusion between the iron and the copper at temperatures below the melting point of copper. The effect, in this way, of fine copper powder is precisely the same as that due to a slow rate of heating or the inclusion of a pre-sintering treatment, whereby the solid diffusion of copper is promoted.

The Influence of Additions to Iron-Copper Mixes

Various additions to iron-copper mixes influence the properties of the compact, including growth. If growth is to be fully understood, it is quite important that the influence of such additions be interpreted, and the effect of three, i.e. graphite, tungsten and phosphorus, will be briefly discussed.

Graphite

The influence of graphite upon the growth of a 5% copper mix is shown in Fig. 10*a*, from which it will be noted that a substantial reduction is achieved by the inclusion of up to 1·5% graphite in the mix. The dimensional change of a pure iron/1·5% graphite mix is exactly nil, and it would appear that the reduction in growth of the iron-copper mix cannot be due to any real change in the shrinkage factor, but must be associated with the growth factor. Since the root cause of growth is alloying of iron and copper, the possible effect of carbon upon the solubility of copper in iron must be considered and related to an influence upon growth.

Information on the iron-copper-carbon system is limited, but available evidence suggests that carbon reduces the inter-solubility of copper and iron. Thus, carbon-free iron can absorb up to 8% of copper at 1,094° C., whilst less than 8% can be absorbed by iron which contains some carbon. If, therefore, graphite is added to an iron-copper mix and is absorbed in the iron at temperatures below the melting point of copper, then less growth will result when the copper melts, since a reduced amount of copper will be absorbed by the iron in the regions of the particle junctions. It is suggested, therefore, that the influence of graphite upon growth is due to the effect of carbon in reducing the inter-solubility of copper and iron. It is an important condition of the argument, however, that the carbon

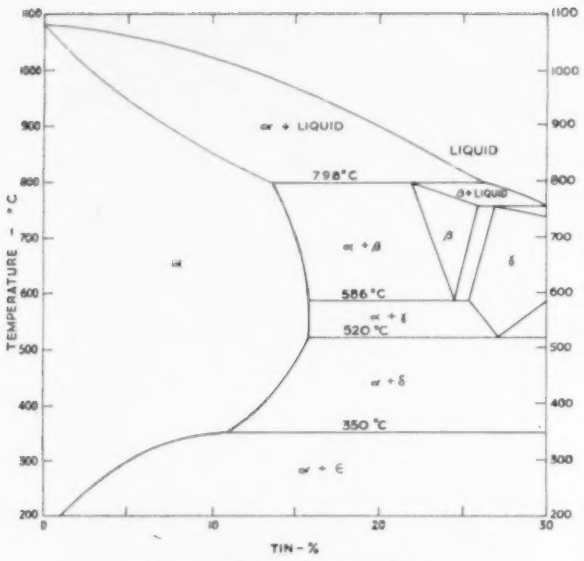


Fig. 11.—Copper-tin alloy diagram.

be in solution in the iron before fusion of the copper develops.

Tungsten

Tungsten reduces the growth of iron-copper compacts according to the graph in Fig. 10*a*. In this case metallic tungsten powder was used, but some observers have noted the same general trend when tungstic oxide was employed. No doubt the oxide would first be reduced during the sintering cycle and then behave as metallic powder.

The shrinkage of iron-tungsten mixtures is very small and indicates that no substantial shrinkage effects are to be expected. As with graphite, it is necessary to look for possible influences of tungsten upon the growth factor, particularly in the way of alloying effects. Knowledge of the iron-tungsten-copper system is limited, but the complete immiscibility of tungsten and copper suggests that tungsten would have an inhibiting effect upon solubility effects in the iron-copper system. It seems probable, therefore, that the influence of tungsten upon growth could be precisely the same as for graphite, i.e. limitation of the solubility of copper in iron.

Phosphorus

Phosphorus, added to iron and iron-copper compacts as iron-phosphide, substantially influences dimensional changes. The influence of phosphorus in iron compacts is primarily due to the existence of a eutectic in the iron-phosphorus diagram at 10·2% phosphorus, which melts at 1,050° C. Sintering of iron-phosphorus mixtures at temperatures above 1,050° C. introduces the eutectic phase and produces sintering characteristics very different from those of iron alone. Fig. 10*b* indicates that substantial shrinkage effects develop at 1,120° C. within a relatively short period of time (15 minutes) with the addition of up to 1·5% phosphorus. The influence of phosphorus upon the growth of a 5% copper-iron material is also presented in Fig. 10*b*, and indicates that the growth effect is very substantially reduced and, at the 1·5% phosphorus level, changes to a shrinkage.

The effect of phosphorus upon the dimensional change of iron is interesting in view of the fact that, as compared with copper, graphite or tungsten, each of which appears to have only a very minor influence upon the shrinkage factor, it produces a substantial change in the latter. This is reflected in a corresponding reduction in the overall growth effect for the iron-copper mix. The graph in Fig. 10*b* suggests that phosphorus probably produces a small reduction in the growth factor itself, since the graphs for the iron and iron-copper dimensional changes are not quite parallel.

To sum up, graphite and tungsten bring about a reduction in overall growth by a direct major influence upon the growth factor, whilst phosphorus reduces overall growth essentially by an increase in the shrinkage factor.

Growth During Infiltration

Dimensional changes during the copper infiltration of a porous iron skeleton have some parallels with the dimensional changes which arise during the sintering of iron-copper compacts. It is common to observe a three dimensional growth effect during infiltration, and alloying of copper with iron is, again, probably the root cause of the expansion.

The copper content of infiltrated compacts is normally of the order of 20% or more and, therefore, exceeds the 8% solubility limit, but infiltration growth effects are generally less than those observed for iron-copper mixes containing 8% copper. This is most likely due to alloying being able to proceed via all the available iron particle surfaces, since the liquid copper is in full surface contact, and is not limited to the regions of the particle junctions, as in the latter case. Overall expansion effects would tend to be greater in the latter case.

Such factors as rate of heating can, of course, have no influence upon infiltration growth, and growth appears to be controlled primarily by the time and temperature of the treatment. Higher temperatures and longer times give more growth and this is consistent with the progress of alloying and, therefore, growth.

The addition of graphite to the iron powder skeleton mix is known to reduce growth during subsequent infiltration. The development of an iron-carbon alloy structure during the sintering of the skeleton presumably reduces the solubility of copper in the iron and thereby brings about a reduction in the growth. Thus the influence of graphite in this instance is precisely similar to its effect upon the growth of iron-copper mixes.

COPPER-TIN MIXES

Bronze is a well established bearing alloy and it is natural that the alloy should be in demand in the form of the self-lubricating type of bearing manufactured by powder metallurgy. Solid bronze bearings normally cover a wide range of composition and, in particular, the tin content may range from 5 to 15%. Whilst sintered bronze bearings can be manufactured with a range of tin content, there has been a tendency to standardise most production upon the 90/10 composition as representing a material with a wide range of application.

The powder metallurgy manufacturing technique permits the inclusion of various additions which would not normally be possible with cast bronze, and graphite is a common inclusion of this type in sintered bronze bearings. Due to its lubricating properties, it is considered to be a useful addition, both from the manu-

facturing and application points of view. The amount normally added is 1·5% by weight.

Various British Standard, S.A.E. and A.S.T.M. specifications have been established in recent years, and the most widely used material is of the type described, i.e. 90/10 bronze, usually with graphite.

The Manufacture of Sintered Bronze

For reasons of powder and sintering characteristics, the manufacture of sintered bronze is based upon the use of pure copper and tin powders, suitably mixed in the appropriate proportions. The copper powder may be made by electrolytic or other means, whilst the tin powder is generally fine, for reasons of best dispersion in the powder mix, and is usually prepared by atomisation. Graphite powder, when required, may be included in the mix.

The solidus temperature of 90/10 bronze is approximately 850° C., and the sintering of compacts is normally carried out in reducing atmospheres at temperatures up to about 800° C. Nickel-chromium continuous mesh belt furnaces are suitable for the sintering operations.

During sintering, the tin powder melts at 232° C. and proceeds to alloy with the copper, so forming the series of solid solutions which characterises the copper-tin alloy diagram (Fig. 11). The fully sintered condition for a 90/10 bronze is a homogeneous *alpha* solid solution, and this is brought about by a gradual homogenising of the intermediate solid solutions as the temperature and the time of the sintering cycle are achieved. Owing to the presence of the liquid tin phase, alloying is complete within a very short period at temperatures of the order of 800° C., and the development of strength is equally rapid. A typical sintering time would be 5–10 minutes.

Dimensional Changes During Sintering

It is possible to achieve both shrinkage and growth effects during the sintering of copper-tin mixes, but growth is by far the predominant feature. As in the case of iron-copper mixes, it is possible to consider the dimensional changes in terms of shrinkage and growth factors, and it is also possible to consider the mechanism of growth as a parallel process to that discussed for iron-copper mixes. In the case of copper-tin mixes, of course, it is the molten tin which migrates to the regions of the copper particle junctions, whereupon alloying and expansion of the metal in these areas develops, so causing the copper particles to move apart and growth to occur.

Unlike iron-copper mixes, there is no specific limit to the solubility of tin in copper, and growth varies widely with the tin content. For the 10% tin alloy, however, it is possible to calculate a simple form of growth factor in the same way as for iron-copper alloys. Since the density of bronze is lower than that for copper (8·7 g./cc. as compared with 8·9 g./cc.), the growth factor will be proportionally greater than for iron-copper, where the densities were assumed to be similar. For a 10% tin alloy, the volume growth would be 13·65% and the equivalent uniform three dimensional linear growth would be 4·55%. This value is to be regarded as a simple guide to the maximum order of growth which is possible, assuming growth to be equal in all directions, and takes no account, for instance, of mass transfer of copper to the particle junctions via solution in the molten tin.

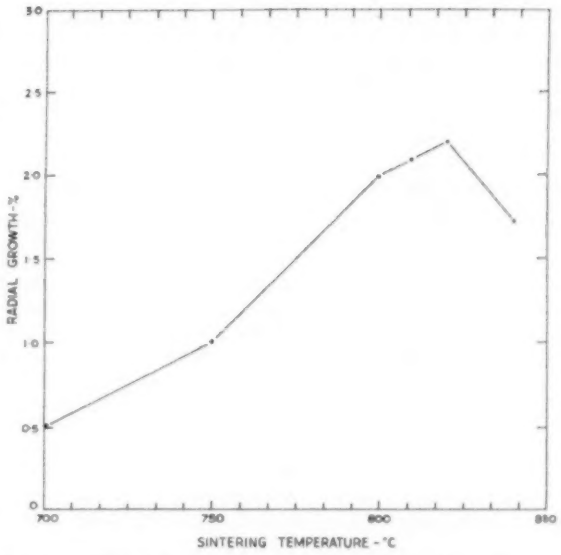


Fig. 12.—Sintering temperature versus growth (copper-tin). Sintering time, 5 minutes.

Dimensional changes in copper-tin mixes are quite critical, and the following factors are among the known variables: characteristics of copper and tin powders; the addition of graphite; compact density; and sintering conditions, including time, temperature, rate of heating and pre-sintering. The influence of some of these factors is considered briefly below.

Influence of Sintering Temperature upon Growth

800° C. has been mentioned as a normal sintering temperature, and Fig. 12 shows how the growth of a typical 90/10 graphite mix varies with conveyor furnace temperature from 700° C. upwards. The growth of copper-tin compacts is not always uniform in the three directions and the length growth is often relatively high. The reasons for this are not clearly understood, and in Fig. 12 radial growth has been plotted. It will be noted that the growth rises to a peak and then declines as temperature further increases.

When considering the dimensional changes of copper-tin mixes in terms of shrinkage and growth factors, it is well to bear in mind that the addition of tin to copper has more far reaching effects upon the dimensional change factors than in the case of copper additions to iron. This is particularly so in the case of the shrinkage factor, and is due to the sintering characteristics of bronze being more critical than those of iron-copper alloys, since the sintering temperature of the former is proportionately nearer the melting point. In addition, the basic growth factor for, say, 90/10 bronze is greater than for iron-copper, and the overall dimensional change effects are, therefore, bound to be more critical with the copper-tin mixes.

The increase of growth with temperature (Fig. 12) up to the peak must indicate an increase in the growth factor with temperature, and this is presumably associated with the progressive fusion of the various intermediate solid solutions. The final melting stage would be that of the *beta* phase at 798° C., and the peak growth is to be associated with this particular stage of the sintering

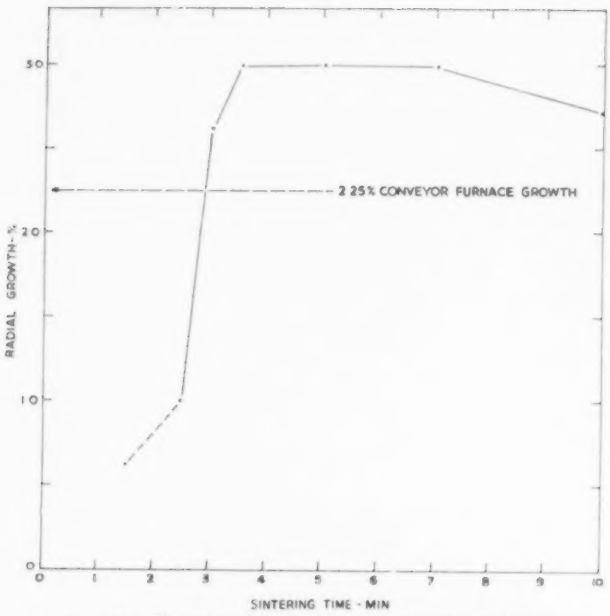


Fig. 13.—Sintering time versus growth (copper-tin). Sintering temperature, 800° C.

cycle. The shrinkage factor must normally become progressively larger as the temperature increases, but apparently less so than the growth factor up to the peak growth, and a reduction in growth is the logical result as the peak growth is exceeded and the melting point is approached.

Sintering Time and Rate of Heating

The influence of sintering time on the growth of a similar type of copper-tin mix is shown in Fig. 13. In this case, compacts were charged for various periods into a batch furnace held at 800° C., and it is apparent from the growth curve that just over three minutes were required in order to reach temperature. On reaching temperature, the growth remained fairly constant for several minutes, and after 10 minutes a slight reduction in overall growth occurred.

It would seem that, following the growth which arose during the initial period to reach temperature, the porous structure which was established was reasonably dimensionally stable, and that an increase in the shrinkage factor, which could be expected to develop with time, did not manifest itself until the end of the sintering cycle (10 minutes).

Information included in Fig. 13 indicates that the growth of the same mix sintered in a conveyor furnace held at 800° C. was 2·25%. The difference between this value and the general value observed in the batch furnace (3%) is accounted for by rate of heating. The way in which rate of heating influences growth in copper-tin mixes is considered to be precisely similar to that in iron-copper mixes, and is associated with a modification to the alloying procedure and direction. The higher rate of heating in the batch furnace has, in this case, had a substantial influence upon the growth.

Powder Characteristics and Compact Density

The choice of copper and tin powders is most important with regard to dimensional change, and Table IV indicates the variation in growth which is observed with various copper and tin powders, together with the influence of compact density in one case. All compacts contained 1·5% graphite.

The finer copper and tin powders produced the lower growths in all cases. As far as the non-sponge copper powders are concerned, the copper powder particle size must basically influence the shrinkage factor (finer powders shrink more) and, in this way, affect the overall growth. The particle size of the tin powder will influence the dimensional change in the same way as does copper powder in iron-copper mixes, i.e. by possible effects upon both shrinkage and growth factors. Shrinkage may be increased by the relative fineness of the pore structure which finer tin powder confers and, on the other hand, may reduce growth by permitting more diffusion across the tin particle/copper particle boundaries in the period prior to full fusion of the tin. Such boundary contacts exist, of course, in greater numbers by the inclusion of a fine tin and, to a lesser degree, when a fine copper powder is employed.

The sponge copper particle structure appeared to behave in a similar fashion to sponge iron powder, i.e. it showed lower growth than a high density particle powder, and no doubt did so for the same reason.

Growth is persistently greater at higher compact densities, in one case to a very substantial degree. The effect undoubtedly is basically one of the influence of a lower shrinkage factor at higher levels of density.

Graphite Additions

Table V shows the typical effect of the addition of 1·5% graphite upon the growth of a 90/10 copper-tin mix. It will be observed that the inclusion of graphite increased the growth, and that this is the opposite effect to that of graphite in iron-copper mixes. It has been previously suggested that the role of graphite in the latter type of mix is due to its influence upon the solubility effects in the iron-copper system; investigation shows that carbon has no solubility relationship whatsoever with either copper or tin, and it must be concluded that no influence upon growth can be derived in this way.

The very fact, however, that neither copper nor tin associate with graphite suggests a way in which the graphite may increase growth. It will be appreciated that flakes of graphite in the green compact must be coated upon the copper and tin particle surfaces and, therefore, must form a barrier between the two metals.

TABLE IV.—EFFECT OF POWDER PROPERTIES AND COMPACT DENSITY ON GROWTH*

Powders		Green Compact Density (g./cc.)	Radial Growth (%)
Copper	Tin		
Electrolytic, −100 mesh	−325 mesh (S.S.1400)	5·5 6·0 6·5	0·35 0·65 1·00
(S.S.500)†	−150 mesh (S.S.700)	5·5 6·0 6·5	2·05 2·10 2·30
Electrolytic, −100 mesh	−325 mesh (S.S.1400)	6·0	1·70
(S.S.300)	−150 mesh (S.S.700)	6·0	2·50
Sponge electrolytic, −100 mesh (S.S.500)	−325 mesh (S.S.1400)	6·5	0·5

* Sintering temperature, 810° C. (conveyor furnace).
† Specific surface in sq. cm./g. optical extinction.

During sintering, direct alloying between the solid copper and tin particles could be limited by the intervening physical barrier of graphite flakes; when full fusion of the tin develops, more tin is available to migrate to the copper particle junctions and, therefore, to bring about more growth. The graphite barrier will normally have relatively less effect upon diffusion between molten tin and solid copper. It will be appreciated that this suggested mechanism of the influence of graphite is precisely similar to that which it is suggested explains the effect upon growth of rapid rates of heating.

Pre-Alloyed Bronze Powder

Irregular, pre-alloyed, bronze powder, manufactured by atomisation, has been proposed as a raw material for the manufacture of sintered bronze bearings. Certain inherent disadvantages have prevented its wide use, but some interesting results upon dimensional change have been observed.

It could be argued that a fully homogeneous alloy powder should only shrink during sintering and, indeed, an initial sample of American powder did precisely this at 800° C. A subsequent sample of British manufacture, of similar average composition, was observed to grow 2·0% under similar sintering conditions, and microexamination of the two powders revealed that the American powder was of a homogeneous *alpha* bronze structure, whilst the British powder particle structure

TABLE V.—EFFECT OF GRAPHITE ADDITION ON GROWTH

Mix	Radial Growth (%)
No graphite	1·35
1·5% Graphite	1·80

(Sintering temperature: 800°C. Conveyor Furnace)

was heterogenous and contained substantial amounts of the tin-rich *delta* phase. When the latter powder was homogenised and then compacted and sintered, it showed a consistent shrinkage.

The heterogeneous particle condition of the British powder sample can be regarded as differing only in degree from the essentially heterogeneous conditions of a powder mix containing copper and tin powder, and the same growth mechanism, based upon the migration of a tin rich liquid, will also apply in the case of the pre-alloyed powder.

Acknowledgments

The author is indebted to the Directors of Bound Brook Bearings, Ltd., for permission to publish this paper.

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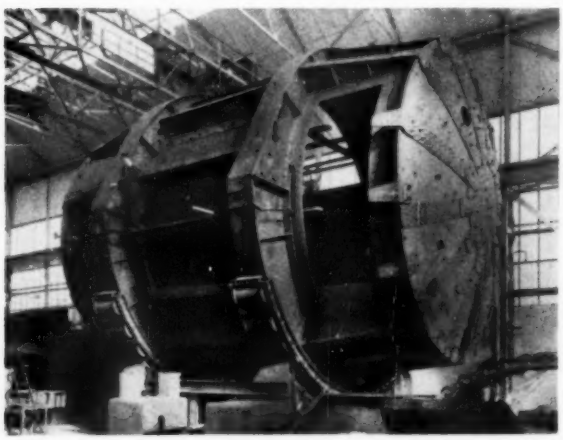
1 Gregg and Daniloff, "The Alloys of Iron and Copper." McGraw Hill & Co.
2 Elliott, J. E., *Metallurgia*, November, 1955, p. 226-234.
3 Gummeson & Foss. Proc. Eleventh Meeting Metal Powder Association. Vol. 1, p. 56–66.

Mixers for Durgapur

TWO Wellman inactive hot metal mixers, each of 800 tons capacity, have been made by Newton Chambers & Co., Ltd., Thorncliffe, near Sheffield, for the £100,000,000 steelworks being constructed at Durgapur, India. They were fabricated to the design and on the instructions of the Wellman Smith Owen Engineering Corporation, Ltd., one of the members of the British Consortium concerned with the India project. Sir Peter Roberts, Bt., M.P., is Chairman of both Newton Chambers and Wellman Smith Owen.

When all the fabricated steelwork for the mixers was completed and the other mechanical parts had been made available, one of these mixers was assembled in the Constructional Shop at the Thorncliffe works as a complete unit. This "proving" process was completely convincing. As the structural parts had been made from templates and all the holes drilled before assembly, it was remarkable that it was unnecessary to alter or reamer a single hole. Both mixers—which involve some 188 tons of structure each, and have an outside shell diameter of 21 ft. 3½ in., and a length of 37 ft.—are being shipped to India. A foreman from Thorncliffe will be going out to supervise and advise on their erection.

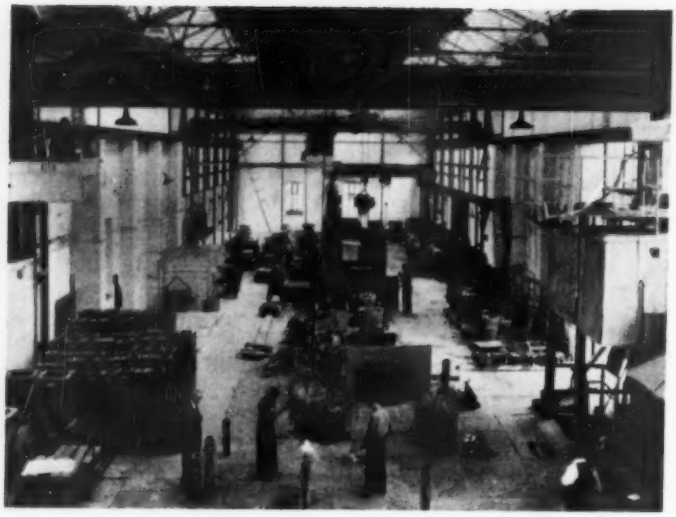


Mixer being assembled at Thorncliffe for proving.

Newton Chambers, as sub-contractors to the Wellman Smith Owen Corporation, are also making for Durgapur works transportation equipment such as 90 ingot casting cars, 260 charging boxes, charging box bogeys, and structural steelwork for six 150-ton ladle cranes.

Symposium on Production of High Vacua

THE Institute of Physics announces that it is arranging a one-day Symposium entitled "Current Developments in the Production of High Vacua" to take place in London on April 17th, 1959. There will be three sessions: (*a*) chemical and ionic pumping in kinetic vacuum systems; (*b*) problems in the production of high vacua in large equipment; and (*c*) analysis of residual gases in kinetic vacuum systems. The symposium is intended mainly for persons working with high vacua. Abstracts (but not preprints) will be circulated before the symposium, the proceedings of which will not be published in full. All communications regarding the symposium should be sent to the Secretary, The Institute of Physics, 47, Belgrave Square, London, S.W.1.



General view of high frequency melting shop.

Steel Works Expansion

Stage I Completed by Arthur Balfour & Co., Ltd.

ALMOST four years ago the Board of Directors of Arthur Balfour & Co., Ltd., the Sheffield steelmakers, considered the long-term sales potential which would arise from world-wide industrial development and expansion, and decided that they should re-deploy and modernise production methods and resources in order that the Company would be in a position to compete in the expanding, but increasingly competitive, world markets, and at the same time give an improved service to existing customers.

Besides the Capital Steel Works in the centre of Sheffield, Balfours own land adjoining Greenland Road, in an industrial development area, where certain of the Company's activities are already carried on. It is the intention that all production shall eventually be concentrated on the Greenland Road site. Working space is available, and areas have been set aside for arc furnace extensions, laboratory concentration, and an improved lay-out of the billet stockyard: provision is also made for bar processing and final inspection.

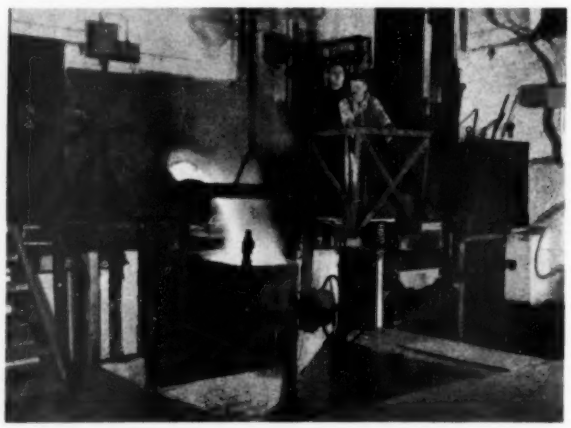
The installation of additional high frequency melting equipment, which was officially opened in October by Sir Peter Roberts, completes the first stage of an overall plan which it is anticipated will take another twelve years to complete, and follows on the modernisation of the heat treatment plant completed three years ago, when pulverised coal fired furnaces were replaced by modern gas fired units. Additional output from the new melting furnaces has necessitated increased heat treatment facilities, and the additional furnaces installed recently embody improvements which are the outcome of the experience and experiments of the Company and Gibbons Bros., Ltd., the furnace designers, during the last three years.

Design, foundations, and installations just completed have been spread over two years, and although most production shops have been affected by structural alterations, there has been no loss of production.

Melting Facilities at Greenland Road

The choice of method for melting a particular steel is determined by a number of factors, such as grade of steel, size of ingot required, tonnage called for, and convenience of production. In the main, all plain carbon tool steels, and tool steels with a low alloy content, are melted in the electric arc furnace, whilst high speed steels and other highly-alloyed steels are melted in the high frequency furnace.

Indications are that there will be increased usage of highly-alloyed tool steels, particularly for the making of tools for long production runs, and it was natural, therefore, that increased melting capacity should be planned accordingly. In producing these steels the Company favours the use of high frequency furnaces, where the power input control is accurate and delicately balanced, and easy of operation by the melter. This ensures a close control of the casting temperature, which is so vital in the production of high quality high speed steels and other alloy tool steels. Furthermore, the stirring action induced into the molten mass of metal by induced electrical currents is advantageous in producing a homogeneous mixture.



Teeming from high frequency furnace.

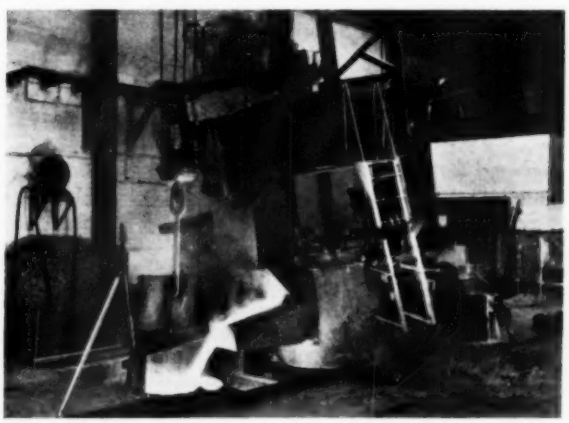
Induction Furnace

The new induction melting plant incorporates a furnace with what is believed to be the highest power per ton in the world, supported by the most modern handling techniques. This Efco unit is provided with a 1-ton and a 10-cwt furnace body, connected through change-over switches to a 600 kVA. high frequency generator. The furnace is tilted by hydraulic power.

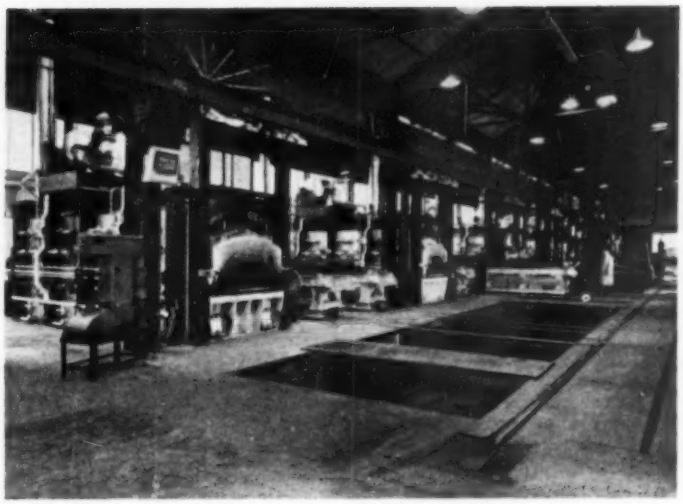
Melting temperatures are recorded on an electronic indicating and recording pyrometer graduated 1,200°—1,750° C. The casting temperature of each heat is recorded on a circular chart, with a specified minimum recording time to avoid a false reading. As an additional check, further temperature readings are taken when the steel is in the ladle.

Ladle preparation has been re-designed in the light of experience, and thus has ensured an even temperature of steel in the ladle throughout the period of casting. The ladle is carried by a 4-ton crane to a position above the ingot moulds, which have already been warmed and coated with an inside surface preparation. Large ingots are cast with the mould standing in a pit, which allows the operator to observe the casting stream from floor level. When the ingots are cool enough to handle, they are stripped from the mould and placed in a heat-insulated cooling pit, which restricts the rate of cooling, and thereby avoids cracking.

Ingots are examined after cooling, head dressed, and checked for internal cavities through the core. They are then painted with the cast number and quality symbol, and held until the final analysis and inspection has been completed. During the last three years the Company has concentrated on quality control and built up a quality control laboratory. This unit is staffed by metallurgists, who carry out physical tests at each stage of production. Every billet used in the production of Balfour tool steel is individually examined to detect surface imperfections, and a modern billet grinding shop, specially designed for ease of work flow and dust-free working conditions, is available for dressing operations.



Teeming from arc furnace.



Gas-fired heat treatment furnaces.

Arc Melting

An interesting feature of the arc melting furnace is the recently installed dust extraction equipment. Use is made of oxygen lancing in the course of steel melting in the furnace, a procedure which raises the temperature of the bath by at least 200° C. and brings in its train dense brown fumes of iron oxide and slag particles, which, prior to the introduction of up-to-date preventive measures, were drawn through the roof and discharged into the atmosphere. On moist windless days, much of these fumes remained in the shop for a time and made the atmosphere unpleasant and the operation of the casting crane hazardous.

The new extraction plant causes the fumes to be drawn in from the furnace doors and ports by a single inlet fan with a paddle blade impellor. This deals with 11,000 cu. ft. of air per minute, and has proved itself capable of coping with the heaviest lancing periods, making the furnace bay atmosphere almost dust free. The weight of dust collected is 11 lb./ton of steel melted ; it has a volume of 0·32 cu. ft.

Tool Division New Bay

The new bay which services the Tool Division, is 250 ft. long and 50 ft. wide, and is the corner stone of a new factory. It is the storehouse which houses the steel requirements of the Tool Division, and supplies materials for the production of a comprehensive range of engineers' tools, hacksaw blades, etc.

Storage provision is in the form of horizontal type racks. This allows for the storing of sheets—for making hacksaw blades—on pallets on top of the racks. Bars which are too heavy for manual handling are located at a point convenient for removal by fork-lift truck. Cutting off machines employing hacksaw blades, bandsaws, parting-off tools, and abrasive wheels—dependent on the size, grade, and shape of off-cuts required—produce suitable units for feeding into the production lines. These units can be transported to the closely adjacent shotblasting apparatus or the recently installed automatic welding apparatus.

Complementary to the new bay is a Birlec 2-ton

electric annealing furnace, which provides an isothermally controlled overnight service. Facilities for other operational processes are in line of production, and a blacksmiths' shop forms a part of the installation.

A new electric sub-station has been built on the site, and land is available for the erection of five more 50 ft. wide production bays.

Metal Cutting Bandsaws

Complementary to the production of hacksaw blades, which have been manufactured by the Company for close on forty years, plant has been put down for the making of metal cutting bandsaws to cater for the increasing demand for this cutting medium. Many of the machines in use were designed by the Company's staff.

Bright finish cold rolled steel strip in coils up to 600 ft. in length provide the basis for manufacture. The initial operation is the milling of the teeth, and twenty lengths of bandsaw are milled at one and the same time. This operation is followed by the processes of tooth setting, tooth hardening, tempering, measuring, and cutting to length. Bandsaws are supplied in the form of coils or in welded lengths.

There is a demand for bandsaws in a wide range of widths and gauges, and with a selection of tooth shapes, dependent on the material to be sawn, the quality of finish desired, and the cutting speeds demanded by the user. Efficiency is largely dependent on the selection of the correct type of bandsaw for a specific operation.

Production has only commenced recently but initial demands are most encouraging.

Billet grinding department.

Quality Control in Europe

THE use of the techniques of quality control has grown rapidly in recent years and with the development of new materials and new methods of production is likely to become very much more important in the future. The Free Trade Area proposals and the European Common Market have brought to the fore the desirability of an international appreciation of standards of quality and the use of quality control procedures. In view of this need, the European Productivity Agency has been responsible for setting up the European Organisation for Quality Control with headquarters in Rotterdam. This body has now invited one organisation from each country belonging to E.P.A. to become the full national member, and the British Productivity Council has been appointed to represent the United Kingdom on the management of the E.O.Q.C.

The activities of the E.O.Q.C. are likely to be of interest to all firms—not only those exporting to the Continent—also to trade associations and to professional institutions, universities and technical colleges. Membership confirms the right (*a*) to receive information on all projects (the first of these, dealing with sampling procedures, is already being developed); (*b*) to receive copies of the E.O.Q.C. Bulletin (published quarterly) which will report developments on quality control techniques in all countries; (*c*) participation in a question and answer service, (*d*) co-operation with the American Society for Quality Control, and (*e*) the opportunity to attend conferences organised by E.O.Q.C.

In order to bring the advantages of membership of the E.O.Q.C. to as wide a section of British industry as possible, and to ensure continuing membership, the British Productivity Council is instituting a subscriber service to which all organisations interested in quality control are invited to participate. Full details of the subscriber service can be obtained from the British Productivity Council, 21, Tothill Street, London, S.W.1.

Process Instrumentation Symposium

A ONE-DAY symposium on Instrumentation in the Process Industries organised by Sunvic Controls, Ltd., was held last month It was attended by more than 50 directors and technical/commercial executives from other companies in the A.E.I. group, as well as from chemical and petroleum companies and electricity authorities. Chairman of the symposium was Mr. N. R. Davis, managing director of Sunvic Controls.

Five papers were delivered by Sunvic executives. They covered techniques and applications of automatic control and instrumentation as at present applied to processes involving continuous flow production—especially oil, chemicals and nuclear power—and also surveyed future development and trends. Considerable emphasis was placed on data processing and automatic computation, particularly in relation to possible applications in fully automatic plant control. The commercial implications of an increasingly important role for instrumentation were also considered.

In addition to hearing these papers and discussing their content, vistors had an opportunity to inspect current Sunvic production of potentiometric recorders, data logging units, reactor instrumentation, and naval control panels, as well as watching a complete data handling unit demonstrated. They also visited the Sunvic mobile exhibition vehicle.

Notch Sensitivity and Directionality in Fatigue in Light Alloy Extrusions as shown by Endurance and Progressive Loading Tests*

By J. McKeown,† D.Sc., M.I.Mech.E., F.I.M.

(*Communication from The British Non-Ferrous Metals Research Association*)

This paper deals with further experimental studies of the progressive loading fatigue test described in an earlier paper by the same author (METALLURGIA, 1956, **54**, 151–158). *It suggests that the test could, with considerable saving of time, replace conventional endurance testing in the assessment of such factors as notch sensitivity, changes in design and suitability of materials used in components and structures.*

THE progressive loading fatigue test developed in these laboratories was described in a previous article.[1] In this test the load on the outer end of a simple cantilever specimen, rotating in a Wöhler type fatigue testing machine, is slowly and continuously increased until the specimen breaks. The stress on the specimen at the moment of fracture has been shown to be simply related to the endurance limit of certain materials. Thus, when the values found for this Dynamic Breaking Stress for a number of alloys based on one metal were plotted against the known endurance limits or fatigue limits of the alloys, a linear relationship was obtained. Such a relationship was found for alloys based on lead, on copper, on iron and on magnesium. In the case of alloys based on aluminium the relationship was less well defined, possibly because some, but not all, of the alloys are structurally unstable in fatigue tests at room temperature.[3]

In the progressive loading test it is desirable to use a rate of increase of load such that true fatigue conditions are induced in the test specimen, and this means that the number of cycles to fracture in such a test shall be greater than say half a million. It is recognised that for a considerable number of these cycles, the alternating stress in the specimen is below the endurance limit of the material, and hence may not be producing any fatigue damage. It would probably be satisfactory to commence the progressive loading test at a stress of 50% of the endurance limit, but since in most cases the endurance limit is not known, it has been considered safer to start all the progressive loading tests from zero stress and accept the loss of time this involves. In the case of those materials which are subject to structural changes during long duration fatigue tests, it is desirable that the rate of stressing in the progressive loading test should be such as to subject the specimen to a sufficient number of cycles to enable these structural changes to occur. In some of the tests recorded below this involved a life in the progressive loading test of 5–10 million cycles.

While the earlier work had not established a completely satisfactory relationship between dynamic breaking stress and endurance limit for the aluminium base alloys examined, it seemed likely from preliminary tests that the progressive loading test was capable of showing, in any one alloy, the differences in fatigue properties resulting from the introduction of stress raisers of any form. The tests now described were made to decide whether this was so, because if the accelerated test was suitable for this purpose, a great deal of time could be saved by using it for notch fatigue studies of materials and of components.

An extrusion of D.T.D. 683 alloy in the form of $\frac{3}{4}$ in. diameter rod was obtained, and a comparison has been made of the dynamic breaking stress and the endurance limit for plain specimens and for specimens with four different notches giving a range of theoretical stress concentration factors from 2·15 to 3·90. Additionally, a large extrusion of B.S. L65 alloy has been examined by both progressive loading and conventional endurance tests, using plain and notched specimens taken both in the longitudinal and short transverse directions.

In this work an encouraging correlation has been found between dynamic breaking stress in the progressive loading test and endurance limit in conventional fatigue tests, and it appears that the progressive loading test is capable of assessing notch sensitivity and directionality effects in a material, with a very considerable saving of time when compared with the conventional endurance tests. Possibly its greatest usefulness lies in its application to the testing of prototypes of components and structures where it may give a quick indication of weak features of design.

Two other large extrusions, one of D.T.D. 683 alloy, and the other of B.S. L65 alloy, have been examined for directionality and notch sensitivity effects, using only the progressive loading tests.

While in this work it appears that some extrusions of these alloys show marked directionality of fatigue properties, it should be remembered that the tests on which this conclusion is based were made on small diameter specimens. Directionality effects in fatigue can be taken as evidence of what may be termed "an inherent notch effect" in the material, and it is well-known that the effect of any notch changes as the ratio of the notch dimensions to the specimen dimensions changes. From this it follows that marked directionality in an extrusion found when using small test pieces may not be nearly so marked if the complete extrusion or a large part of it becomes the test piece. It is necessary, therefore, to give the warning that the marked directionality in fatigue properties found in some of the

* The work described in this paper was made available to members of the B.N.F.M.R.A. in a confidential research report (B.R.A. 1176) issued in January, 1958.

† Head of Mechanical Testing Section, B.N.F.M.R.A., London.

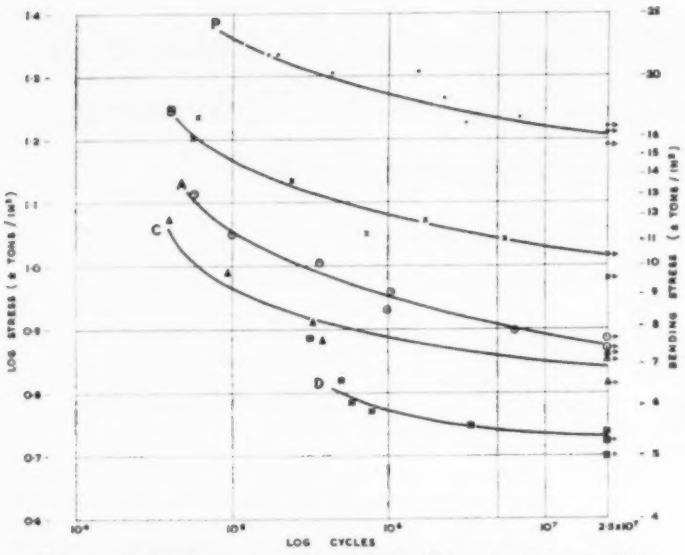


Fig. 1.—Endurance curves for D.T.D. 683 extruded rod (RVS).

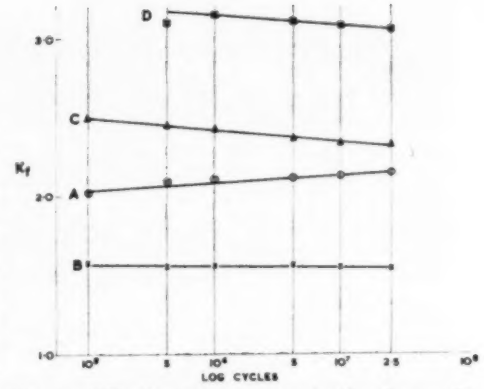


Fig. 2.—Effective stress concentration factor, K_f, versus cycles in endurance tests on D.T.D. 683 extruded rod (RVS).

extrusions when small test pieces were used does not necessarily mean that these results are typical of what may be expected from such extrusions in actual service applications.

Endurance and Progressive Loading Tests on Extruded Rod of D.T.D. 683 Alloy

This material had been extruded from a three-hole die as rods $\frac{3}{4}$ in. diameter, and after cutting into suitable lengths for tensile and fatigue test pieces, was solution treated for 4 hours at 460° C., quenched in water at 20° C., precipitation treated for 24 hours at 130° C. and cooled in still air.

Tensile tests on each of the rods showed that the material was reasonably uniform, the 0·1% proof stress ranging from 38·7 to 40·1 tons/in.² the tensile strength from 41·0 to 42·0 tons/in² and the elongation on $4\sqrt{A}$ from 7 to 10%.

Fatigue tests were made in a single point loading Wöhler machine, one machine only being used for this work in an attempt to reduce scatter of results. The speed was 3,000 r.p.m., while the laboratory temperature averaged 20° C. Tests were made on plain specimens and on specimens containing the following four notches :—

A. 0·020 in. root radius, 0·020 in. deep, $K_t = 2·15$
B. 0·004 in. root radius, 0·004 in. deep, $K_t = 2·75$
C. 0·004 in. root radius, 0·008 in. deep, $K_t = 3·30$
D. 0·004 in. root radius, 0·020 in. deep, $K_t = 3·90$

Notches *A* and *B* were semi-circular, while *C* and *D* had an included angle of 60°. The diameter of the plain specimens was 0·3125 in. and all the notched specimens had this same root diameter. At least six specimens were used for each determination of endurance limit, and when scatter was found, 12 were used. The endurance curves given in Fig. 1 show that scatter was most marked with the plain specimens and decreased as the intensity of stress concentration due to the notch increased.

Progressive loading tests were made in the same machine on four of each type of specimen, and again in these tests the scatter of results decreased as the intensity of stress concentration due to the notch increased. The rate of increase of stress in these tests was approximately 2·6 tons/in² per 10^6 cycles.

The results of the tests are given in detail in Table I. From the average endurance curve for each type of specimen, the endurance limit corresponding to four different numbers of cycles has been obtained and the values of K_f, the effective stress concentration factor, evaluated and plotted in Fig. 2. This factor has also been determined for the progressive loading tests as the ratio of the dynamic breaking stress for the plain specimen to that of the notched specimen. It appears that K_f in the progressive loading tests has approximately the same value as in the endurance tests. The values of K_f have been plotted against those of K_t, for

TABLE I.—D.T.D. 683 EXTRUDED ROD (RVS).

Type of Test Piece	Endurance Limit (± tons/in²) at :						K_t	K_f in Endurance Tests at :						Progressive Loading Test			Ratio : Dynamic Breaking Stress / Endurance Limit at $2·5 \times 10^7$
	10^5	5×10^5	10^6	5×10^6	10^7	$2·5 \times 10^7$		10^5	5×10^5	10^6	5×10^6	10^7	$2·5 \times 10^7$	Breaking Stress (± tons/in²) Average (Range)	Cycles Fracture ÷ 10^6 Average	K_f	
Plain	22·9	19·5	18·6	17·1	16·6	16·0	1	—	—	—	—	—	—	20·3 (19·8–20·7)	7·43	—	1·27
Notch A	11·4	9·4	8·9	8·1	7·8	7·5	2·15	2·01	2·08	2·10	2·11	2·13	2·14	10·4 (10·3–10·5)	4·08	1·95	1·40
Notch B	14·6	12·6	12·0	11·0	10·7	10·4	2·75	1·57	1·55	1·55	1·56	1·55	1·54	13·1 (12·6–13·6)	4·93	1·55	1·26
Notch C	9·2	8·0	7·7	7·2	7·1	6·9	3·30	2·49	2·44	2·43	2·37	2·34	2·32	8·2 (8·0–8·4)	3·28	2·48	1·19
Notch D	—	6·3	5·9	5·5	5·4	5·4	3·90	—	3·10	3·16	3·11	3·08	2·96	7·4 (6·9–7·7)	2·76	2·74	1·27

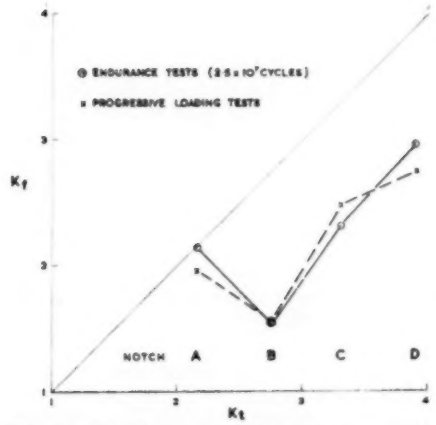


Fig. 3.—Effective versus theoretical stress concentration factors for D.T.D. 683 extruded rod (RVS).

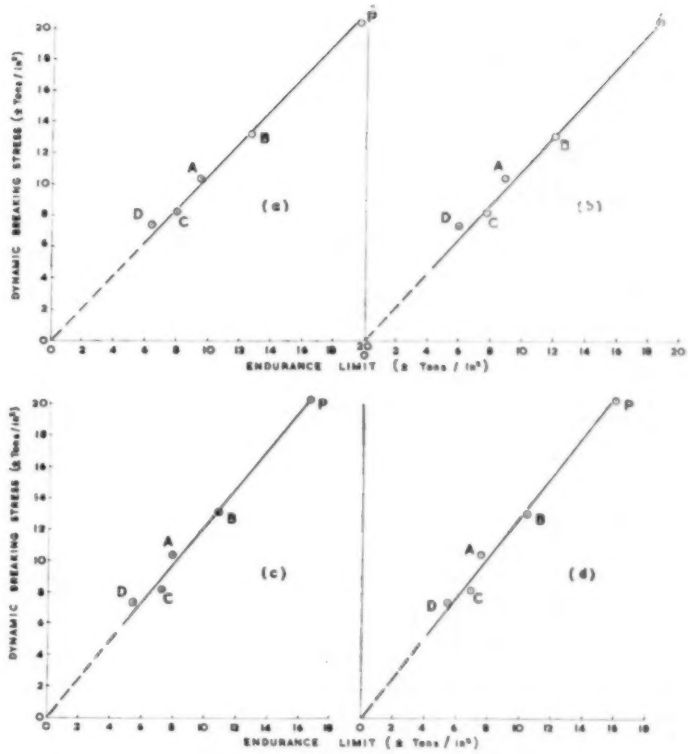


Fig. 4.—Dynamic breaking stress versus endurance limits for plain and notched specimens from D.T.D. 683 extruded rod.

(a) For endurance limit at 5×10^5 cycles.
(b) For endurance limit at 1×10^6 cycles.
(c) For endurance limit at 10×10^6 cycles.
(d) For endurance limit at 25×10^6 cycles.

both endurance and progressive loading tests, in Fig. 3, and a reasonable degree of correlation between the tests is shown.

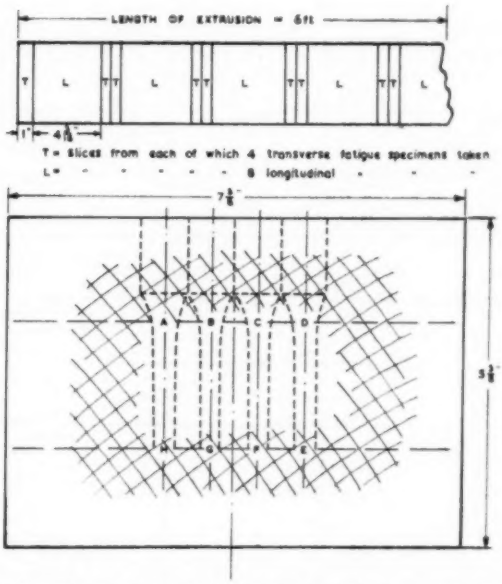


Fig. 5.—Transverse slice showing positions of transverse fatigue specimens. In the slices marked L the longitudinal fatigue specimens were located with their centre lines passing through the points A, B, ... H on the cross section.

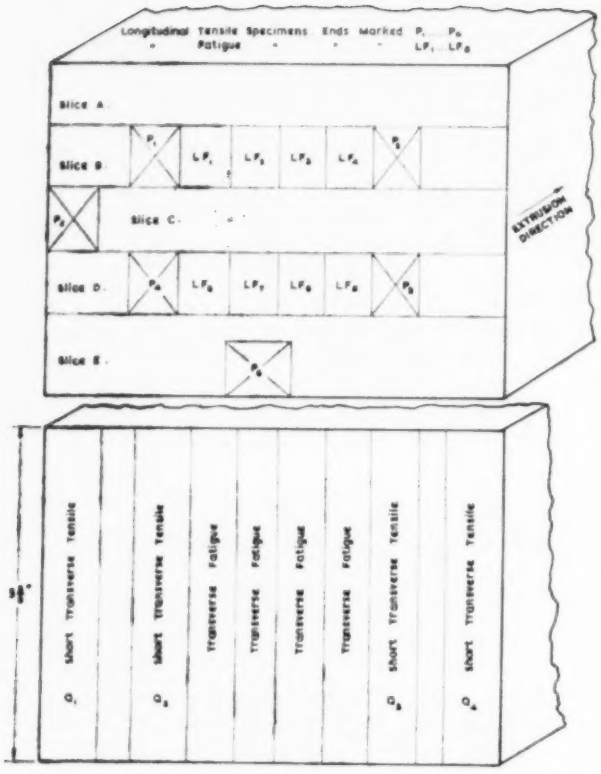
The linear relationship between the progressive loading and the endurance tests is shown in Fig. 4, where dynamic breaking stress is plotted against endurance limits at four different numbers of cycles for the specimens with and without notches. It is seen that straight lines fit the various points quite well, and these lines, when extrapolated, pass through the double zero. In fact, of course, they do not reach the double zero because it has been shown[2] that K_f does not become infinite as the notch is made sharper and deeper. The results show that the progressive loading test can be used with a considerable saving in testing time to estimate the effective stress concentration in fatigue produced by notches with K_t values up to about four. Other tests in progress are designed to determine whether the same is true for notches with still higher values of K_t and K_f.

Directionality Effects and Notch Sensitivity in Fatigue in a Large Extrusion of Alloy L65

The extrusion on which these tests were made was in the fully heat treated condition. Its cross-section was $7\frac{3}{8}$ in. $\times$ $5\frac{3}{8}$ in., and a thin transverse section cut from the extrusion was polished and etched and showed a faint extrusion pattern in the position indicated by the cross-hatching in Fig. 5.

The extrusion was cut into lengths as shown in Fig. 5 to provide longitudinal and transverse test pieces. The location of the transverse fatigue specimens was such that the position of maximum bending stress was in the region covered by the extrusion pattern, and this was also true for the longitudinal specimens.

Tensile specimens were also taken in the following directions :—



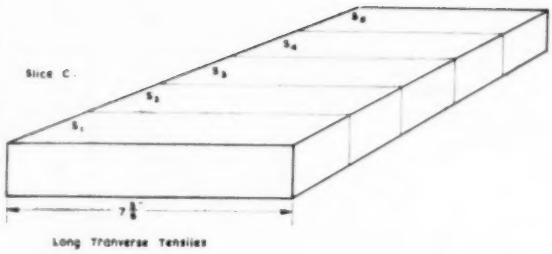


Fig. 6.—Positions in extrusion of fatigue and tensile test specimens.

TABLE II.—TENSILE TESTS ON L65 EXTRUSION.

Specimen Location	Mark	Proof Stress (tons/in²) 0·1%	Proof Stress (tons/in²) 0·2%	Tensile Strength (tons/in²)	Elongation (% on $4\sqrt{A}$)
Longitudinal	SCT				
	P1	28·0	28·5	31·5	11·2
	2	28·9	29·5	32·0	10·2
	3	28·4	29·0	31·9	10·4
	4	28·2	28·7	31·6	9·6
	5	30·0	30·5	33·2	9·6
	6	29·3	29·6	31·9	11·2
Long Transverse	SCT				
	S1	23·4	24·3	26·7	1·0
	2	24·0	25·0	26·6	1·6
	3	24·1	24·8	26·8	1·6
	4	23·9	24·8	27·0	2·4
	5	24·0	25·2	26·7	2·4
Short Transverse	SCT				
	Q1	27·9	28·5	30·2	5·6
	2	24·2	25·0	27·3	3·5
	3	23·6	24·5	27·0	2·4
	4	27·9	28·0	30·5	7·2

(*a*) Longitudinal
(*b*) Long transverse
(*c*) Short transverse
} See Fig. 6.

Tensile Tests

Standard screwed-ended test pieces having a diameter of 0·357 in. on the reduced section were machined from the samples, the positions of which are indicated in Fig. 6. The results of the tensile tests are given in Table II. The strengths of all the long transverse specimens were consistently lower than those of the longitudinal specimens and were very similar to those of the short transverse specimens. The elongation on $4\sqrt{A}$ was lower for both long and short transverse than for longitudinal specimens. Also, the longitudinal specimens showed some necking, which was completely absent in the transverse specimens. It appears likely that had short transverse tensile specimens been taken in the positions occupied by the transverse fatigue specimens (see Fig. 6), they would have had strengths and elongations comparable with those of the long transverse specimens.

Endurance Tests

For these tests, and also for the progressive loading tests dealt with below, test pieces, both longitudinal

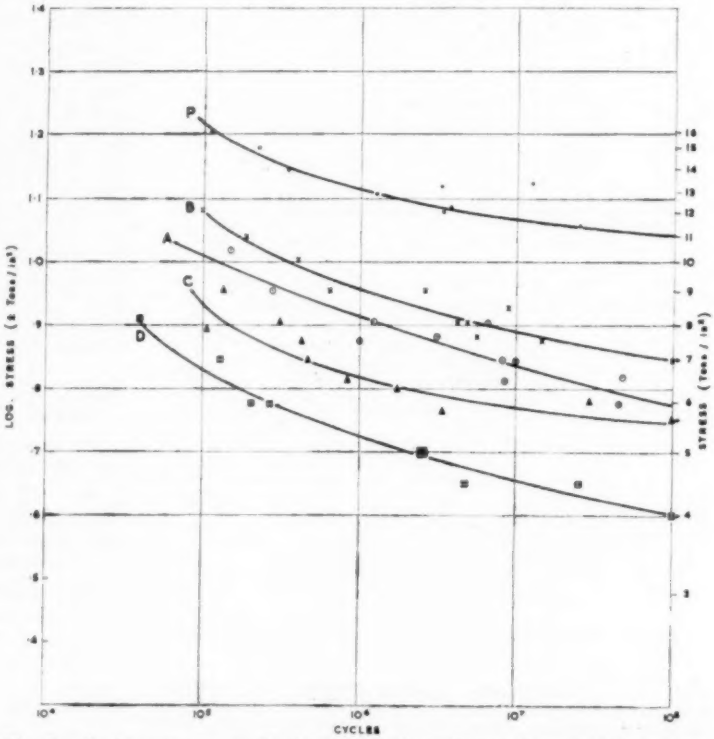


Fig. 7.—Endurance curves for longitudinal specimens from L65 extrusion (SCT).

and short transverse, were machined as plain specimens and with the same notches as were used in the work on the D.T.D. 683 extruded rod. Specimens of each type were taken throughout the extrusion in a random distribution. The endurance tests were made on two single point loading Wöhler machines at a nominal speed of 3,000 r.p.m. The results obtained are shown plotted on double logarithmic scales in Figs. 7 and 8. The detailed results of the tests, given in Table III, show that there is little, if any, directionality effect in this extrusion in respect of fatigue properties at long endurances, a finding which would not have been expected from the results of the tensile tests.

The ratios of the endurance limits of the plain specimens to average tensile strengths for endurances of 10^5, 10^6, 10^7 and 10^8 cycles are plotted in Fig. 9. This diagram suggests that the transverse specimens were tending to a constant value for this ratio, i.e., tending towards a fatigue limit, whereas the longitudinal specimens gave no indication of such a limit. The calculated values of K_f at 10^5, 10^6, 10^7 and 10^8 cycles are plotted in Fig. 10; K_f increases with increase in cycles, unlike the unusual result shown in Fig. 2 where K_f showed little change with increasing cycles.

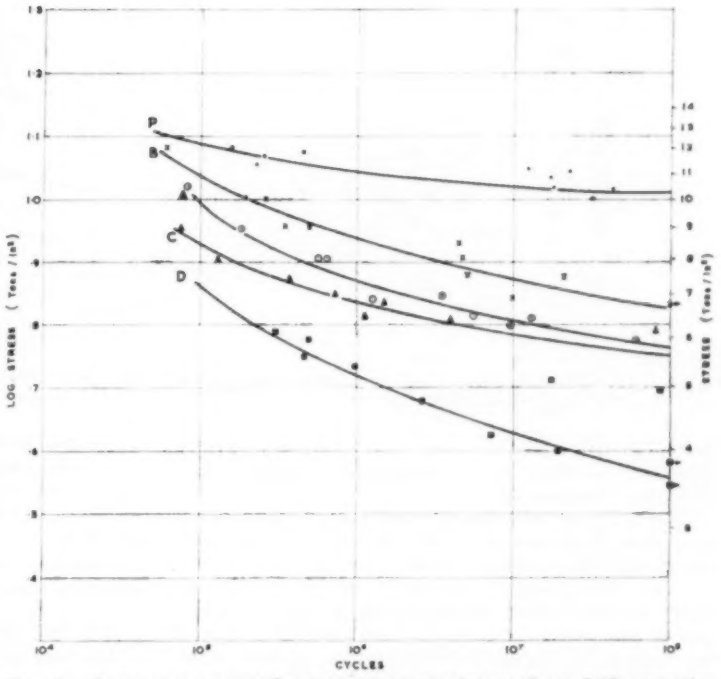


Fig. 8.—Endurance curves for transverse specimens from L65 extrusion (SCT).

Progressive Loading Tests

Four specimens of each type were tested in progressive loading the rate of stress increase being approximately 2·6 tons/in² per 10^6 cycles. The average value of dynamic breaking stress for each type of specimen is given in Table III, which also contains the values of the effective stress concentration factor obtained in this test.

Comparison of Effective and Theoretical Stress Concentration Factors.

This comparison is given in Table III, and also in Figs. 11A and 11B, for both the endurance and the progressive loading tests. Diagrams (*c*) in both these figures show that for a particular notch the effective stress concentration factor as obtained in the endurance tests is very similar in both longitudinal and transverse specimens, again indicating no marked directionality

TABLE III.—L65 ALLOY (SCT) 7½ in. × 5½ in. EXTRUSION.

Specimen Type	Endurance Limit (± tons/in²) at :				Dynamic Breaking Stress (± tons/in²) Average (Range)	Cycles in Progressive Loading Test to 10^6 Average	K_t	K_f in Endurance Tests at :				K_f in P.L. Test	K_f Relative to Plain Longitudinal Specimens	
	10^5	10^6	10^7	10^8				10^5	10^6	10^7	10^8		On Endurance Limit at 10^8 Cycles	On Dynamic Breaking Stress
Longitudinal Plain	16·2	13·0	11·8	11·0	14·8 (14·5–14·9)	5·77	1	—	—	—	—	—		
Notch A	10·2	8·2	6·7	5·9	9·0 (8·3–9·4)	3·88	2·15	1·59	1·59	1·76	1·87	1·65		
Notch B	12·0	9·0	7·8	7·0	11·2 (10·7–11·6)	4·23	2·75	1·35	1·45	1·52	1·58	1·32		
Notch C	8·5	6·5	5·9	5·5	8·2 (8·1–8·3)	3·12	3·30	1·91	2·00	2·00	2·00	1·81		
Notch D	6·7	5·3	4·5	4·0	7·1 (6·6–7·3)	2·66	3·90	2·42	2·46	2·62	2·75	2·09		
Transverse Plain	12·3	11·1	10·5	10·2	13·2 (10·7–15·3)	5·03	1	—	—	—	—	—	1·10	1·12
Notch A	9·9	7·4	6·4	5·8	9·1 (8·7–9·5)	3·40	2·15	1·24	1·50	1·64	1·76	1·45	1·90	1·63
Notch B	10·9	8·7	7·4	6·7	10·3 (9·8–10·8)	3·92	2·75	1·13	1·28	1·42	1·52	1·28	1·64	1·44
Notch C	8·5	6·8	6·1	5·6	8·0 (7·8–8·4)	3·07	3·30	1·45	1·63	1·72	1·82	1·65	1·96	1·85
Notch D	7·3	5·2	4·2	3·6	6·6 (6·3–7·1)	2·48	3·90	1·69	2·14	2·50	2·84	2·09	3·04	2·24

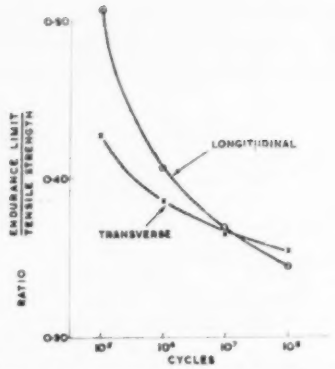


Fig. 9.—Ratio of endurance limit to tensile strength for plain specimens from L65 extrusion.

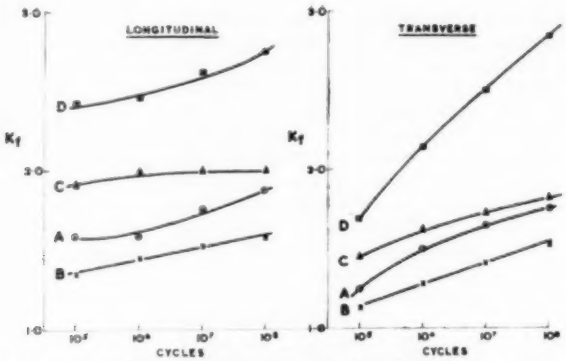


Fig. 10.—Effective stress concentration factor, K_f, versus cycles in endurance tests on L65 extrusion.

effect. There is about the same order of agreement when this factor obtained by the progressive loading tests is considered (diagram (*d*)).

With the most severe notch used there is the greatest measure of disagreement in K_f between the progressive loading and the endurance tests (see diagrams (*a*) and (*b*)), and it is thought that this is due to the greater degree of stress relief at the notch in the progressive loading test, where the nominal stress rose to 7·1 tons/in² compared with the stress at the endurance limit at 10^8 cycles, namely 4·0 tons/in² (both these stresses refer to longitudinal specimens ; for transverse specimens the corresponding stresses are 6·6 and 3·6 tons/in²).

If this view is correct, still better correlation between the endurance and progressive loading tests would be obtained if the rate of loading in the latter were decreased so that the dynamic breaking stress did not rise so much above the endurance limit.

In Fig. 12 dynamic breaking stress is plotted against endurance limits at 10^5, 10^6, 10^7 and 10^8 cycles for both longitudinal and transverse, plain and notched specimens, and in each case the points are seen to lie reasonably well on straight lines which, if extrapolated, would pass through the double zero. It follows therefore that endurance limit is directly proportional to dynamic breaking stress.

Use of the Progressive Loading Test

The fact that the endurance and the progressive loading tests gave similar K_f/K_t ratios for any given notch, although notches of different shape did not give straight line plots of K_f against K_t, whether determined by endurance or progressive loading tests, indicates that the accelerated test may be used with considerable confidence and much saving of time in the testing of prototype components or structures. It should have a wide field of usefulness in indicating weaknesses, in respect to

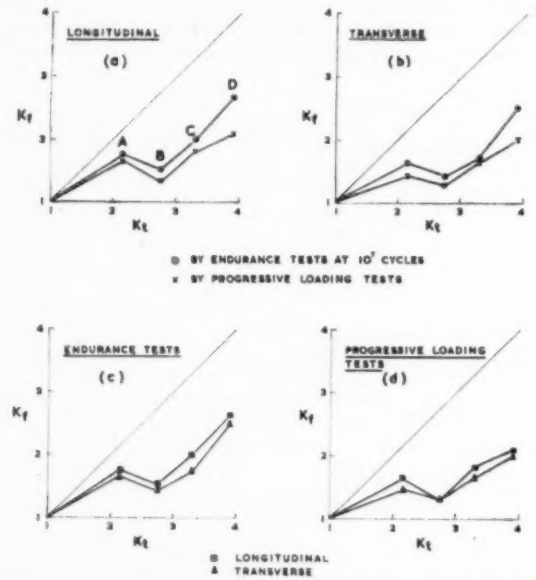


Fig. 11A.—Effective versus theoretical stress concentration factors for L65 extrusion (endurance limits at 10^7 cycles).
(a) (b) Comparison of the two test methods.
(c) (d) Directionality effects.

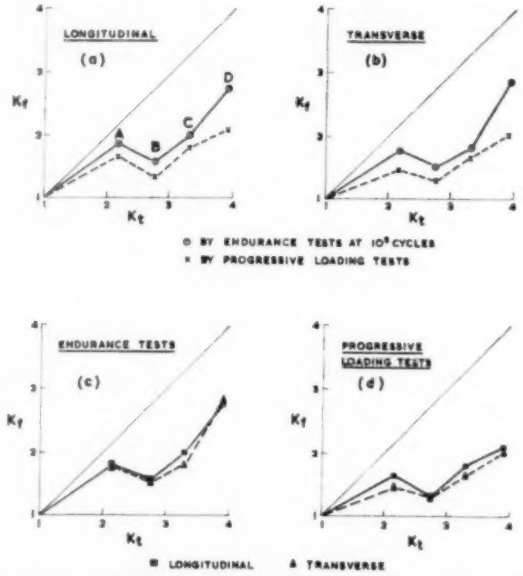


Fig. 11B.—Effective versus theoretical stress concentration factors for L65 extrusion (endurance limits at 10^8 cycles).
(a) (b) Comparison of the two test methods.
(c) (d) Directionality effects.

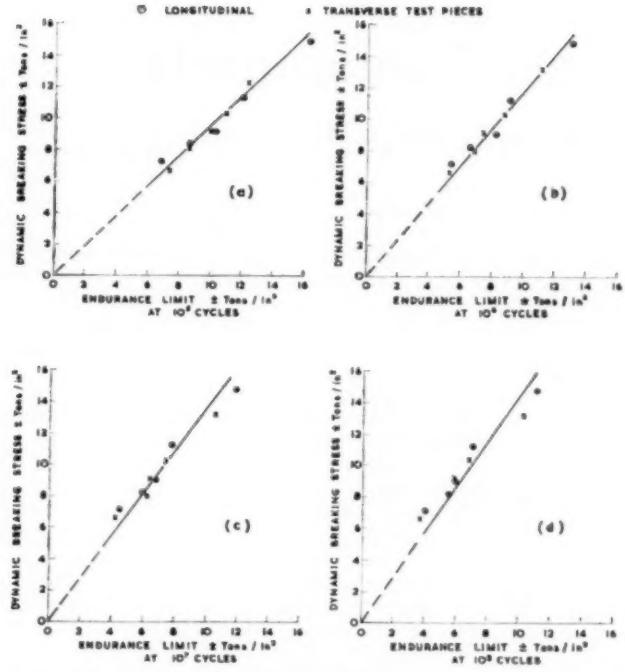

○ LONGITUDINAL × TRANSVERSE TEST PIECES
DYNAMIC BREAKING STRESS ± Tons / in²
(a)
(b)
(c)
(d)
ENDURANCE LIMIT ± Tons / in² AT 10⁷ CYCLES
ENDURANCE LIMIT ± Tons / in² AT 10⁸ CYCLES

Fig. 12.—Dynamic breaking stress versus endurance limits for longitudinal and transverse specimens from L65 extrusion (SCT).

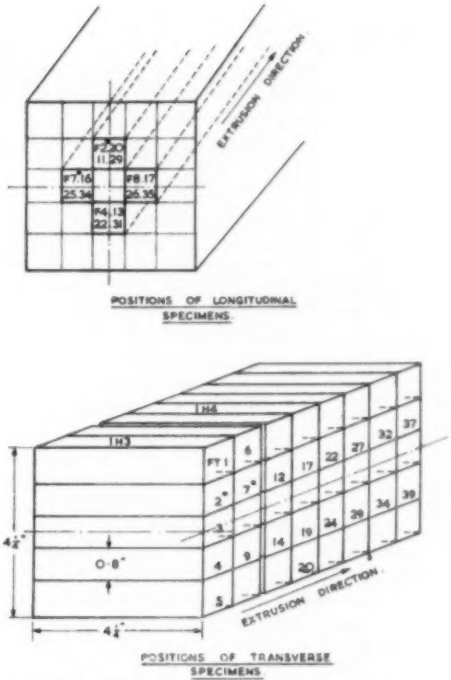


Fig. 13.—Positions of fatigue specimens in D.T.D. 683 extrusion.

fatigue resistance, of points of design and possibly also of unsuitability of materials used.

Directionality in Two Large Extrusions as Shown by Progressive Loading Fatigue Tests.

Earlier unpublished Association work had shown that these particular extrusions had marked directionality of tensile properties. An insufficient amount of each was available for endurance tests.

The first extrusion was of D.T.D. 683 alloy and had a cross-section $4\frac{1}{4}$ in. $\times$ $4\frac{1}{4}$ in. The positions from which the progressive loading fatigue specimens were taken are shown in Fig. 13. When the blanks had been cut out they were solution treated for $7\frac{1}{2}$ hours at 461° C., quenched in water at 20° C., precipitation treated for six hours at 132° C., and cooled in still air. Fatigue specimens of the five types used in the work described above were machined from the heat treated blanks.

Progressive loading tests were carried out in triplicate and the average values obtained are given in Table IV. The rate of increase of stress was approximately 2·8 tons/in²/10^6 cycles. The results obtained are shown plotted in Fig. 14 and the following points may be noted :

(1) At each of the notches used the effective stress concentration factor was much smaller than the theoretical factor.

(2) The plain transverse specimens have behaved relative to plain longitudinal specimens as if they contained an inherent stress concentration with an effective value of 1·75, which would correspond to a theoretical value of 3·3 in longitudinal specimens.

(3) In transverse specimens, only when notches having a theoretical stress concentration factor greater than 3 were used did the notch produce any further reduction in dynamic breaking strength and hence, by inference from the previous work, in fatigue strength.

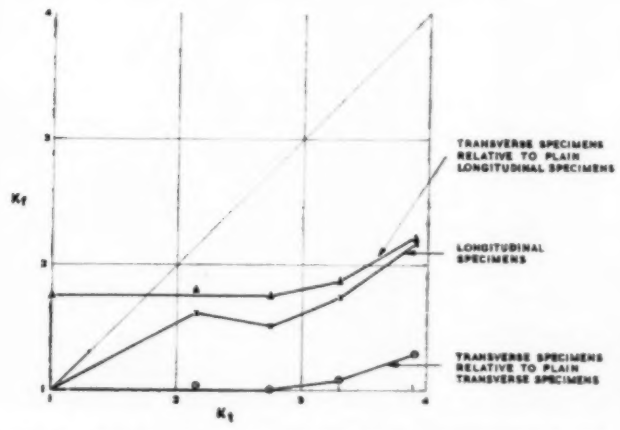
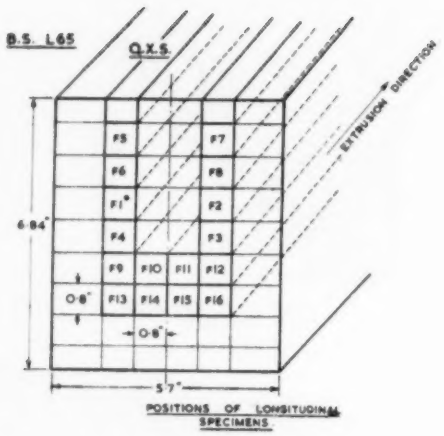


Fig. 14.—Effective versus theoretical stress concentration factors for $4\frac{1}{4}$ in. square D.T.D. 683 extrusion.

The second extrusion was of B.S. L65 and had a cross-section 6·84 in. $\times$ 5·7 in. The positions from which the specimens were taken are shown in Fig. 15. The blanks were solution treated for three hours at 507° C., quenched in water at 20° C., precipitation treated for $5\frac{1}{2}$ hours at 183° C., and cooled in still air.



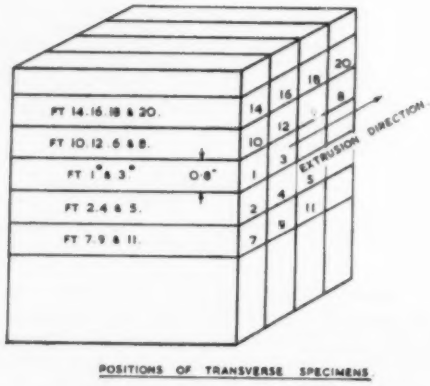


Fig. 15.—Positions of fatigue specimens in L65 extrusion.

TABLE IV.—PROGRESSIVE LOADING FATIGUE TESTS ON LONGITUDINAL AND TRANSVERSE SPECIMENS FROM A 4½ IN. SQUARE EXTRUSION OF D.T.D. 683 ALLOY.

Direction of Specimen in Extrusion	Type of Specimen	Average Dynamic Breaking Stress (± tons/in²)	Stress Concentration Factors		K_f Relative to Plain Longitudinal Specimens
			K_t	K_f	
Longitudinal	Plain	17·2	1	—	
	Notch A	10·6	2·15	1·62	
	„ B	11·4	2·75	1·52	
	„ C	9·9	3·3	1·74	
	„ D	7·9	3·9	2·18	
Transverse	Plain	9·9	1	—	1·74
	Notch A	9·6	2·15	1·03	1·79
	„ B	9·9*	2·75	1·00	1·74
	„ C	9·2	3·3	1·08	1·87
	„ D	7·75	3·9	1·28	2·22

* Two of the three specimens broke away from the notch.

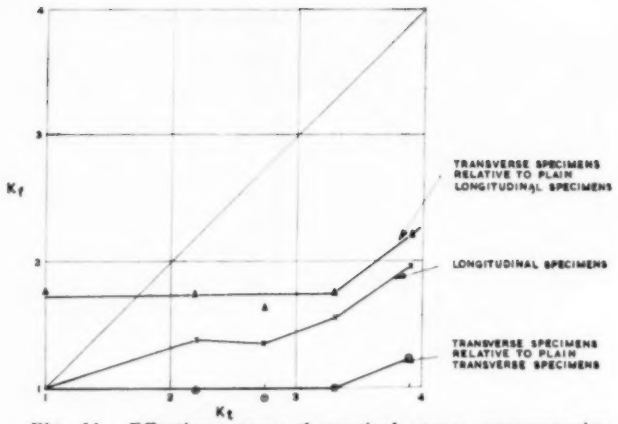


Fig. 16.—Effective versus theoretical stress concentration factors for 6·84 × 5·7 in. L65 extrusion.

TABLE V.—PROGRESSIVE LOADING FATIGUE TESTS ON LONGITUDINAL AND TRANSVERSE SPECIMENS FROM A 6·8 in. × 5·7 in. CROSS-SECTION EXTRUSION OF B.S. L65 ALLOY.

Direction of Specimen in Extrusion	Type of Specimen	Average Dynamic Breaking Stress (± tons/in²)	Stress Concentration Factors		K_f Relative to Plain Longitudinal Specimens
			K_t	K_f	
Longitudinal	Plain	15·6	1	—	
	Notch A	11·3	2·15	1·38	
	„ B	11·6	2·75	1·35	
	„ C	10·1	3·3	1·55	
	„ D	8·0	3·9	1·95	
Transverse	Plain	8·8	1	—	1·77
	Notch A	9·0	2·15	0·98	1·74
	„ B	9·6	2·75	0·92	1·63
	„ C	8·8	3·3	1·00	1·77
	„ D	7·1	3·9	1·24	2·20

The results of the progressive loading tests, which were made at a rate of increase of stress of 2·8 tons/in²/10^6 cycles, are given in Table V and are plotted in Fig. 16. The points noted for the square extrusion of D.T.D. 683 alloy apply equally to this extrusion of B.S. L65.

The compositions of these two extrusions are given in Table VI.

Acknowledgments

The author wishes to thank the Director and Council of The British Non-Ferrous Metals Research Association for permission to publish this paper.

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2 Frost, N. E. and Phillips, C. E., "Studies in the Formation and Propagation of Cracks in Fatigue Specimens," *Proc. Internat. Conference on Fatigue of Metals*, 1956, pp. 432–438.

3 Hanstock, R. F., "Fatigue Phenomena in High Strength Aluminium Alloys," *J. Inst. Metals*, 1954–5, **83**, 11.

TABLE VI.—SPECTROGRAPHIC ANALYSES OF MATERIALS TESTED.

Description of Material	BNF Mark	Composition % (Aluminium Remainder)								
		Zn	Mg	Cu	Fe	Si	Cr	Mn	Ti	Ni
Extruded rod D.T.D. 683	RVS	6·2	2·8	0·39	0·32	0·16	n.d.	0·48	tr. <0·01	n.d.
7½ in. × 5½ in. Extrusion of B.S. L65	SCT	0·068	0·64	3·6	0·32	0·69	n.d.	0·92	0·089	n.d.
4½ in. × 4½ in. Extrusion of D.T.D. 683	IH3, 4	5·69	3·10	0·92	0·24	0·24	0·05	0·33	—	—
6·8 in. × 5·7 in. Extrusion of B.S. L65	QXS	0·10	0·68	4·15	0·43	0·77	—	0·72	0·15	0·03

Aluminium Forging Production

Northern Aluminium Install 4,000 ton Press

NORTHERN Aluminium Company's capacity for the production of hand forgings has been greatly increased by the recent installation in their Birmingham Works of a 4,000-ton direct-acting hydraulic press. It is also available for closed-die and no-draft forgings, and for the pre-working of cast stock prior to rolling and extrusion in the Company's works at Banbury and Rogerstone.

The press, by Becker and Van Hullen, was originally installed in the Dornier Works, Germany, and after the war was confiscated by the Dutch Government as war reparations. It was acquired by the firm of Van der Heist and Zonen, of The Hague, for the pressing of automobile body parts, and before installation at Birmingham it has been extensively rebuilt according to recommendations made by The Loewy Engineering Co., Ltd. In its original form, the press was too high for Northern Aluminium Company's forging bay, the method of retracting the ram being by two cylinders mounted at the top of the press ; the main alteration has therefore been the replacement of these by two push-back cylinders, so reducing the height to 27 ft.

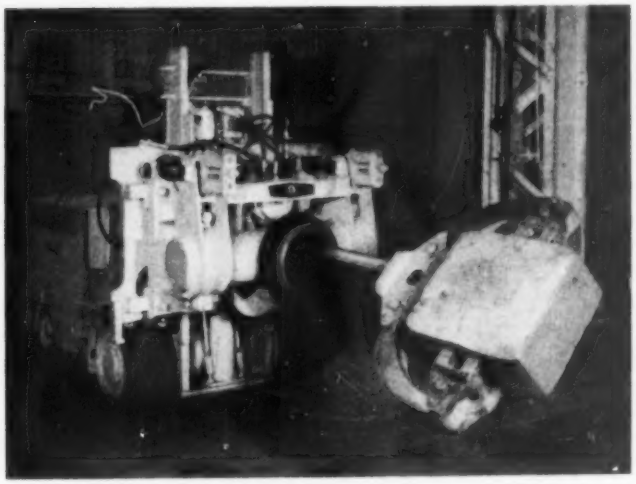
The press is fitted with ejector gear which takes the form of a 24 in. diameter ram housed in a foundation 17 ft. deep. From the bed plate rise the four main columns, 16 in. in diameter, surmounting which is the top crosshead. Below this is secured the main ram, 53 in. in diameter, on which the main cylinder, with the bolster secured to its lower face, moves up and down. Because of this principle of operation, the main cylinder has guides at its top and bottom, giving very accurate alignment between the upper and lower platens. The working space between the columns is 7 ft. and the press has a stroke of 6 ft., which permits 9 ft. 1 in. of daylight between top and bottom platens.

Operation of the press is by means of a modern system of fingertip control through electro-hydraulic valves with a range of speeds varying from 0·08 to 0·50 in./sec. This variation in speed is achieved by the selective use of twelve Fraser mono-radial pumps, each driven by a 50 h.p. motor capable of delivering oil to the press at a rate of 20 gal./min. To lower the cylinder, oil is passed into it from a 2,500 gal. refill tank under an air pressure of about 50 lb./sq. in. ; when contact is made with the work, the prefill valve closes and the pumps take over, delivering oil direct to the press at a total pressure of 4,000 lb./sq. in.

The press was originally laid down to increase the scope of the hand forgings that could be offered by the Company, especially for use in the aircraft industry, and among those already produced are several weighing 1,500 lb. each. However, used in conjunction with the 45,000 lb. hammer already installed, it will also enable the Company to offer bigger closed-die forgings, up to about 700 lb. in weight, and it has already proved its usefulness in enabling cast stock to be pre-worked more economically, and in bigger sizes, than hitherto.

The handling of such large sizes during hand forging would clearly be impossible by the usual method, namely suspension from an overhead crane and manipu-

These large hand forgings were produced on the 4,000-ton press for an aircraft prototype : the largest of them weighed 1,500 lb.



Stock for forging is handled by this mechanical manipulator, which takes the form of a hydraulically operated arm mounted on a fork-lift truck.

lation by tongs. A mechanical manipulator has therefore been brought into use, which is essentially a hydraulically-operated arm, incorporating a means of gripping the stock, mounted on a fork-lift truck. The actual manipulating mechanism, which is of Salem Brosius design, made under licence by Head Wrightson and Co., Ltd., and styled a Manipulet, has a capacity of 1,500 lb. It has great flexibility of movement, enabling the stock to be hoisted, lowered, tilted, moved from side to side and rotated through 360°, without the truck having to be moved. Of Yale and Towne design, the truck itself has a capacity of 10,000 lb., which includes the power required to operate the hydraulic system of the Manipulet.

In the New Year Honours List

THE names of those honoured by H.M. The Queen in the New Year Honours List included the following.

KNIGHTHOOD

A. F. BURKE, O.B.E., Deputy Chairman and Managing Director de Havilland Aircraft Co., Ltd.
MAJOR-GENERAL C. A. L. DUNPHIE, C.B., C.B.E., D.S.O., Managing Director, Vickers, Ltd.
J. W. LAING, C.B.E., President, John Laing and Son, Ltd.
R. P. LINSTEAD, C.B.E., Rector, Imperial College of Science and Technology, University of London.
J. A. MILNE, C.B.E., Chairman and Managing Director, J. Samuel White and Co., Ltd. President, Shipbuilding Conference.
E. J. PODE, J.P., Managing Director, Steel Company of Wales, Ltd.
K. T. SPENCER, C.B.E., M.C., Chief Scientist, Ministry of Power.

C.M.G.

C. WAITE, Chairman and Joint Managing Director, Consolidated Tin Smelters, Ltd.

K.B.E.

G. W. H. GARDNER, C.B., C.B.E., Director, Royal Aircraft Establishment, Farnborough.

C.B.E.

S. E. CLOTWORTHY, Managing Director, Northern Aluminium Co., Ltd.
M. COOK, Chairman, Metals Division, Imperial Chemical Industries, Ltd.
T. C. FINLAYSON, Chairman, Woodall-Duckham, Ltd.
P. T. FLETCHER, Deputy Managing Director, Industrial Group Headquarters, Risley, Atomic Energy Authority.
R. A. LOVELL, Chief Mechanical Engineer, Ministry of Transport and Civil Aviation.
L. T. MORTON, Joint Managing Director, Clarke Chapman & Co Ltd.
R. J. PINDER, Managing Director, Esso Petroleum Co., Ltd.
J. H. REED, Managing Director, Ericsson Telephones, Ltd.
R. H. SCHLOTEL, Director, Engine Research and Development, Ministry of Supply.
J. McWATERS STOREY, Managing Director, Dewrance and Co., Ltd.

O.B.E.

R. F. BALLARD, General Manager, Kolster-Brandes, Ltd.
A. BAMBROUGH, General Manager, Richard Garrett Engineering Works, Ltd.
T. BANCROFT, Production and Works Director, Blackburn and General Aircraft, Ltd.
D. L. BROWN, Assistant Director of Engine Research and Development, Ministry of Supply.
A. R. BUGLER, Constructor, H. M. Dockyard, Portsmouth.
S. CHARD, Superintendent, Grade "B", Royal Ordnance Factory, Glascoed.
H. ECCLES, H.M. Senior Engineering Inspector of Factories, Ministry of Labour and National Service.
L. ESSEN, Senior Principal Scientific Officer, National Physical Laboratory.
F. C. EVERETT, Principal Scientific Officer, Armaments Production Division, Ministry of Supply.
D. J. FARRAR, Chief Designer, Guided Weapons, Bristol Aircraft, Ltd.
C. V. HILL, M.C., lately Refining Adviser, British Petroleum Co., Ltd.
C. S. JENKINS, lately Regional Director, North Midlands Region, Ministry of Power.
A. E. MORRISON, Managing Director, Moore and Wright (Sheffield), Ltd.
P. W. MUMMERY, Senior Principal Scientist, Reactor Division, Atomic Energy Research Establishment, Harwell.
A. RITCHIE, Principal Scientific Officer, Scottish Home Department.
T. S. ROBERTSON, Principal Scientific Officer, Naval Construction Research Establishment, Admiralty.
MAJOR P. L. TEED, Deputy Director, Department of Aeronautical Research and Development, Vickers-Armstrongs (Aircraft), Ltd.
H. N. WOOD, Managing Director, Hugh Wood and Co., Ltd.

M.B.E.

J. S. BARNES, Director and General Manager, Whites Shipyard (Southampton), Ltd.
J. H. BAXTER, Apprentice Training and Welfare Officer, Parsons Marine Steam Turbine Co., Ltd.
A. BOWMAN, Dock Manager, Smith's Dock Co., Ltd.
R. J. BRACEY, lately Head, Optics Department, British Scientific Instrument Research Association.
F. S. DENNARD, Technical, Grade 1, Atomic Weapons Research Establishment.
E. DENNIS, Managing Director, E. Dennis and Son, Ltd.
A. E. DENTON, Works Manager, S. G. Brown, Ltd.
F. G. DUDLEY, Welfare Officer, Cars Branch, Morris Motors, Ltd.
A. C. EMERY, Chief Draughtsman, Telecommunication Group, Plessey Company, Ltd.
FLIGHT-LIEUTENANT J. FORMBY, Flight Commander, Meteorological Vertical Ascent Flight, Short Brothers and Harland, Ltd., Royal Air Force, Woodvale.
I. H. HOGG, A Senior Research Planning Officer, Research and Development Branch, Industrial Group Headquarters, United Kingdom Atomic Energy Authority, Risley.
L. PINDER, lately Senior Inspection Officer (Aircraft), Ministry of Supply.
L. J. PITT, Safety and Civil Defence Officer, Fielding and Platt, Ltd.
F. PRICE, Head Foreman Sheet Metal Worker, Cammell Laird and Co., Ltd.
J. RANDELL, Chief Ship Draughtsman, John Brown and Co. (Clydebank), Ltd.
C. ROWLEY, Assistant Chief of Armament Design, Vickers-Armstrongs (Engineering), Ltd.
P. C. RUGGLES, Senior Engineer, English Electric Valve Co., Ltd.
W. H. SIMMONS, Chemist II, Royal Ordnance Factory, Bridgewater, Somerset.
D. SLEATH, Chief Draughtsman, Instrument Department, Laurence Scott and Electromotors, Ltd.
W. S. STAMBRIDGE, Consultant, Rubery Owen and Co., Ltd.
C. STAMPS, Shops Superintendent, Dorman Long (Chemicals), Ltd.
G. B. TRESILIAN, lately Chemist and Metallurgist, Edward Curran Engineering Co., Ltd.
F. R. WARNER, Head of Sales Department (Contracts Division), The General Electric Co., Ltd.
S. WIGGLESWORTH, Safety and Civil Defence Officer, Imperial Chemical Industries (Dyestuffs), Huddersfield.
A. L. WILSON, Engineer, Technical Class, Grade I, Explosives Research and Development Establishment, Ministry of Supply.
A. WINSTANLEY, M.M., Manager, Smithy and Metal Working Section, United Glass Bottle Manufacturers, Ltd.
R. B. WITHERINGTON, Works Manager, Lambhill Ironworks, Ltd.
K. J. WOODGATE, Superintending Inspector, Aeronautical Inspection Service, Air Ministry.

(Continued on page 16)

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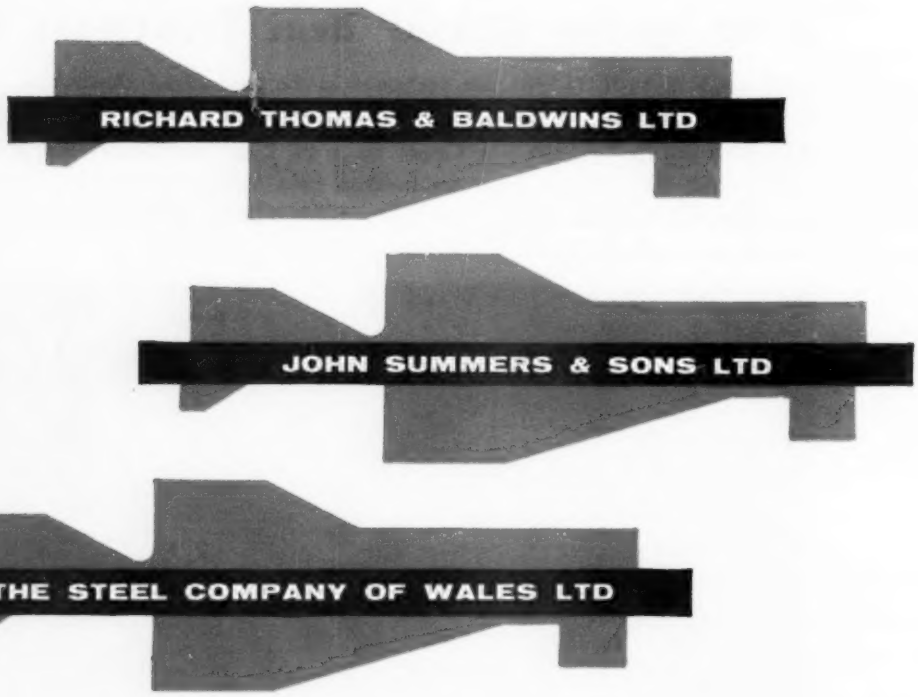

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NEWS AND ANNOUNCEMENTS

Physical Society Exhibition

THE PHYSICAL SOCIETY'S 1959 Exhibition will be held from January 19th to 22nd, in the Old and New Halls of the Royal Horticultural Society, Westminster. This Exhibition, which is the 43rd of the series, will include 153 exhibitors and will represent a cross section of the latest developments in British physics.

As is well known, it is the policy of the Society to show as many new instruments and techniques as possible, and it is hoped that the Exhibition of 1959 will maintain and exceed its previous high standards. A large number of universities, hospital physics departments and research organizations are again participating, thus assuring a high proportion of purely research exhibits. As is usual, exhibits will show the trend of instrumentation in industry, research and teaching for the next twelve months. Visitors to the Exhibition will be most interested in the selection of instruments from Swedish universities and research organizations, which is being shown this year by invitation of the Council of the Physical Society. This Swedish exhibit is under the auspices of the Royal Swedish Academy of Engineering Sciences.

The scope of the Exhibition is very wide and includes such items as fully developed instruments for the tracking of artificial earth satellites. Another recent advance in technology—the automatic factory with the requisite complex control of machine tools—is well represented by the various forms of diffraction gratings and their applications to the accurate positioning of tools. Such new instruments as the Maser, for microwave techniques, are shown for the first time this year.

Brazing Course

BRAZING offers to industry a most versatile method of fabrication by means of which it is possible to make many articles which would be difficult or uneconomic to produce any other way. It is, however, a complex subject; nearly every metal may be used as filler material, and all methods of heating may be applied. Before the technical and economic possibilities of the process may be fully appreciated, it is necessary to have a proper understanding of the fundamentals of brazing, the selection of filler metals and heating methods, and the correct approach to design. The School of Welding Technology is therefore organising a special Course on Brazing Technology and Design, with a view to giving up-to-date information about the wide range of brazing processes available, and guidance on their application. Further particulars of the Course, which will be held from February 9th to 13th, 1959, may be obtained from the Institute of Welding, 54, Princes Gate, Exhibition Road, London, S.W.7.

Conference on Magnetism

THE INSTITUTE OF PHYSICS announces that it is arranging a Conference on "Some Aspects of Magnetism" to take place in Sheffield from 22nd–24th September, 1959. The subjects to be covered by the conference include: (*a*) fundamental theories of ferro-, ferri- and anti-ferromagnetism, including magnetic structure; (*b*) theories of technical magnetization processes, including hysteresis, coercivity, anisotropy and directional effects; (*c*) theoretical and experimental studies of domain phenomena in bulk materials and thin films; and (*d*) experimental and theoretical studies of antiferromagnetism in metals and non-metals.

Each session will be opened by an invited speaker and offers of other contributions should be submitted to the Conference Secretary at The Institute of Physics, 47 Belgrave Square, London, S.W.1., before 31st January, 1959. The conference is intended mainly for persons working in the field. Abstracts (but not preprints) will be circulated before the conference, the proceedings of which will not be published in full.

Plastic Coated Steel Exhibition

AN exhibition devoted entirely to the fabrication and applications of Stelvetite, the new plastic-coated steel sheet, is to be held at the Royal Festival Hall, London, from January 13th to 16th, by the manufacturers, John Summers and Sons, Ltd., of Shotton, Chester. Announcing this, John Summers say that it is being arranged in order to demonstrate to their wide range of customers and other interested companies exactly what can be done with Stelvetite.

There will be a series of demonstrations including spot welding (which can be done without damage to the P.V.C. coating), high frequency welding, lock forming, printing and drum sealing. Stelvetite in all its available colours and gauges will be shown with a large selection of the things now being produced in the material, such as office furniture and machines, chemical equipment, refrigerators, domestic water-heaters and clocks.

Admission to the exhibition will be by invitation only except on the last day (Friday), when it will be open to persons holding tickets which can be obtained upon application to John Summers and Sons, Ltd. (M.R. & D.), St. Ermin's, Caxton Street, London, S.W.1.

International Metal Finishing Conference

THE International Council for Electrodeposition and Metal Finishing announces that an International Conference, the Fifth in this Series, will take place in June 1959, at Detroit, U.S.A. The last International Conference was held in London in 1954, when it was decided to hold such Conferences every five years. The Conference will deal with technical, scientific and practical aspects of electrodeposition and metal finishing. It is expected that some thirty or more papers on these subjects will be presented by specialists from America, Great Britain, the European Continent and other parts of the world. The American Electroplaters' Society will act as the host Society. The Conference coincides with the 50th Anniversary of this Society, which will simultaneously stage its Annual Congress in Detroit, so that many interesting events, both technical and social, will be open for participation by those attending the International Conference.

All interested in metal finishing are invited to attend the Conference, which will be the outstanding world

event in this field in 1959. Further information relating to the programme and arrangements generally, may be obtained from Dr. S. Wernick, Hon. Secretary, Institute of Metal Finishing, 32, Great Ormond Street, London, W.C.1.

Metallographic Techniques Course

A COURSE on Modern Metallographic Techniques, comprising seven lectures and four practical periods, will be held at the Northampton College of Advanced Technology, St. John Street, London, E.C.1, on successive Wednesday afternoons, commencing on January 14th, 1959.

The aspects to be covered by the course include: recent developments in polishing and etching techniques; special methods of illumination in microscopy, including polarised light, phase contrast, and tangential illumination; micro hardness testing; electron microscopy; T.V. microscopy; microradiography; and colour photomicrography.

Enrolment may be effected in person or by post; in the latter case those wishing to enrol should supply the following information: (*a*) name and address; (*b*) qualifications; (*c*) name of employer (for record purposes only); and enclose the fee of two guineas and a stamped addressed envelope.

Founders' Company Medals Presented

AT the Annual Dinner of the Worshipful Company of Founders, held at the Mansion House, on December 18th, 1958, the Master of the Company, Mr. G. W. Ilsley, presented, in the presence of the Lord Mayor and Sheriffs of the City of London, Founders Company Medals to four Liverymen of the Company, to mark their services to the Art and Mystery of Founding, and to the Company.

Medals were presented to Dr. J. G. Pearce, C.B.E., and Dr. J. E. Hurst, C.B.E., J.P., in appreciation of their help to the Company in the formulation of the Founders Company Fellowships, and the administration of them since their inception. The remaining two Liverymen, Mr. C. C. Booth, J.P., and Mr. J. J. Sheehan, received their Medals for their valuable services to the Company, with special reference to their assistance in organising the annual Spring visits of members to foundries.

Magnesium Prices

As from January 1st, the price of pure magnesium ingot supplied by Magnesium-Elektron, Ltd., is reduced to 2s. 4d., 2s. 3½d., and 2s. 3d. per lb., for under one ton per month, one to ten tons per month, and ten tons and over per month, respectively. There is also a reduction in the price of notched bar, under half a ton per month to 2s. 10½d. per lb., and half a ton and over per month to 2s. 9½d. per lb. Prices include delivery to customers' works in the United Kingdom.

Second Liquid Fuels Conference

A RESIDENTIAL conference organised by the Institute of Fuel will be held in Torquay from Monday evening, May 11th, 1959, to Thursday afternoon, May 14th, 1959. The object of this Second Conference on Liquid Fuels is to bring up to date information presented to the First Conference in Birmingham in 1948. All interested, whether members of the Institute or not, are welcome.

A list of papers to be presented, an enrolment form, and a booklet of hotel accommodation may be obtained from the Secretary of the Institute of Fuel, 18, Devonshire Street, London, W.1. Intending participants are advised to book their hotel accommodation before the end of January.

Personal News

MR. W. BARR, O.B.E., Chief Metallurgist and a Director of Colvilles, Ltd., has been nominated by the Council for election as President of the Iron and Steel Institute. He will take office at the Annual General Meeting in May.

MR. G. D. ELLIOT, O.B.E., has been appointed Deputy General Works Manager of Appleby-Frodingham Steel Company, a branch of The United Steel Cos., Ltd. On April 1st next, he will succeed as General Works Manager MR. J. D. JOY, who became Deputy General Manager of the Company on January 1st. MR. N. D. MACDONALD, Superintendent of Appleby-Frodingham's Ore Preparation Plants, is to succeed Mr. Elliot as Works Manager (Iron).

MR. R. H. MARDELL has been appointed London Area Sales Manager for General Refractories, Ltd., in succession to MR. T. S. AIKMAN, who has recently retired. Mr. Mardell has been assisting Mr. Aikman for several years as London Area Sales Representative.

ENGLISH STEEL CORPORATION, LTD., announce that MR. W. E. A. REDFEARN has been appointed a Director. Mr. Redfearn has been associated with English Steel Corporation, Ltd., and its predecessors since 1915, and is Deputy Managing Director of English Steel Forge and Engineering Corporation, Ltd., and a Director of English Steel Rolling Mills Corporation, Ltd.

IN consequence of the retirement of the Director, DR. J. G. PEARCE, C.B.E., on December 31st, 1958, the Council of The British Cast Iron Research Association has made the following appointments: MR. H. MORROGH, Deputy Director, becomes Director, and DR. H. T. ANGUS, Assistant Director, becomes Deputy Director. MR. T. E. WHITESIDE, will continue as Secretary with special duties with respect to the Association's finances.

MR. F. H. DAVIS, who joined the Metallurgical Section of the Research Department of Metropolitan-Vickers Electrical Co., Ltd., in 1944, has been appointed Assistant Superintendent, Foundries.

Obituary

WE regret to record the sudden death on December 4th, as a result of a heart attack, of MR. RICHARD LLOYD, the youngest son of the late Mr. R. T. Lloyd of Birley Carr, Sheffield. Mr. Lloyd was a Director of The Effingham Steel Works, Ltd., and London Area Manager of their associated firm, Marsh Brothers & Co., Ltd. On his discharge from the Army in 1918 he joined the Staff of Marsh Brothers & Co., Ltd., and was subsequently appointed to take charge of the Sales Office of The Effingham Steel Works, Ltd., under the late Mr. H. T. Bradbury, Managing Director. In 1931 he went to the firm's London Office. During the Second World War, Mr. Lloyd was appointed to a Sub-Committee of the Machine Tool Control.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Clear Anodising Magnesium

A CLEAR anodic coating for magnesium alloys that can be applied in less than a minute has been developed by The Dow Chemical Company. The new coating is used under a lacquer or varnish for maximum corrosion protection. Up to now, manufacturers desiring a " metallic look " for magnesium products have used lacquer or varnish over the bare metal. The clear anodise plus one of the top coats provides, it is claimed, much better protection than the top coat alone. Lacquer or varnish tinted with commercial dyestuffs can be applied over the clear anodise to obtain a transparent effect in a wide variety of colours which have good permanence and are not washed out by detergents.

The clear anodising treatment is a modification of the standard Dow 17 anodic treatment, which results in yellow or green opaque deposits. The anodising baths are identical, but the new process operates at 40 volts compared with the 70–90 volts for the standard Dow 17. Patents have been applied for in many countries.

Step by step, the procedure is as follows :

(1) The metal is buffed with a 320-grit abrasive to achieve uniform brightness of the desired lustre.
(2) Parts are immersed in an alkaline cleaner for 3—10 minutes, then given a cold-water rinse.
(3) Parts are immersed in the anodising bath for less than 1 minute, then given a cold-water rinse and a hot-water rinse.
(4) When parts are dry, lacquer or varnish is sprayed on and baked dry (typical time and temperature : 20 minutes at 250° F. (120° C.)). Certain lacquers and varnishes can be air dried.

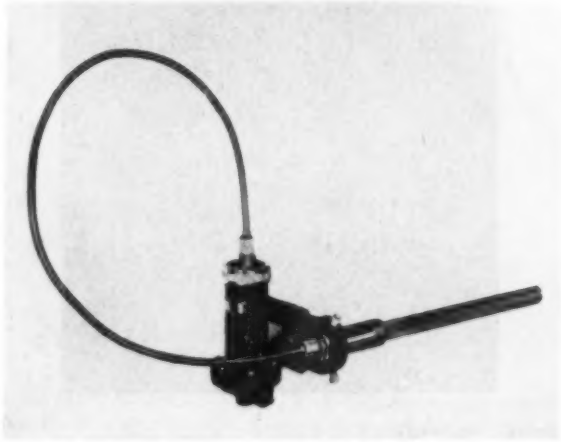
In 20% salt-spray tests, in the Dow Laboratories, magnesium finished with clear anodise plus lacquer or varnish has passed 500 hours with virtually no change in appearance. The treatment can be applied to all forms of magnesium, such as sheet, extrusions, die castings, and sand castings and forgings.

Dow Chemical International, Ltd., Midland, Michigan, U.S.A.

Temperature Transmitter

THE latest version of the Sunvic pneumatic temperature transmitter uses high purity helium as filling gas in the thermal system. Helium has been selected for several reasons. Firstly, it is completely inert chemically, and damage to the bulb can have no adverse effect on a process, even in the case of explosives or food. Secondly, the thermal conductivity of helium is good, ensuring rapid response of the instrument to changes in temperature. Moreover, use of helium makes it possible to test the complete thermal system in a mass spectrometer, so that even the most minute leak can be detected. This, combined with the fact that the thermal system is filled at comparatively low pressure, so that volumetric changes of the bulb at high temperatures are reduced to a minimum, ensures excellent long-term stability.

The system is inherently linear as it is a true constant-volume thermometer, and does not permit any changes in temperature.



As with other Sunvic temperature transmitters, in the new Model 33H, the thermal element can be changed without use of tools, so that replacement of a damaged element, or changing the range, can be performed simply and *in situ*. Construction is extremely simple ; no beams, pivots, links or bearings are used, so that wear and friction are eliminated and deadspot and hysteresis are at a remarkably low level. The thermal systems are of copper or stainless steel and bulbs are available in a variety of forms and sizes. Copper bulbs will withstand 1,000 lb./sq. in. static pressure, and stainless steel bulbs up to 1,500 lb./sq. in. Spans from 50° F. (30° C.) to 900° F. (500° C.) can be covered, and no " standard " ranges are offered, each instrument being made to customers requirement. Since the filling medium is high purity helium, very low temperatures indeed can be measured, and the thermometer is sensitive to changes in measured temperature of the order of 0·01% of range.

Sunvic Controls, Ltd., 10, *Essex Street, London W.C.2.*

Preheating and Stress Relieving of Welds

THE application of armoured electrical resistance heaters in the heat treatment field has found wide acceptance by engineers concerned with the preheating and stress-relieving of welds and heat treatment generally. Muffle furnaces, gas jets and induction coils are replaced with lengths of armoured heater consisting of nickel-chromium resistance wires specially insulated to withstand working temperatures of up to 800° C. (1,472° F.) and covered overall with a flexible nickel alloy sheath of $\frac{5}{16}$ O.D.

The heaters, which can be applied to curved or flat surfaces, are placed about the area to be heated, connected to an electrical supply, and then covered with sections of high temperature resistant lagging. The source of the electrical supply depends on the location

of the job, but as armoured heaters operate at safe voltages of 50, 75 or 100, a welding transformer, or generator or a mains transformer can be used. The temperature is measured by a thermocouple or couples connected to a simple indicator, the readings from which enable the operator to control the temperature by on/off switching or voltage regulation. Other forms of temperature indicators, recorders and control gear are available.

By the careful design of the heaters and their positioning with respect to the lagging, a large amount of heat can be dissipated in the required area, for example, an 18 ft. length at 75 volts is rated at 3 kW. All heaters are re-usable and are available in standard lengths according to the rating required. To assist in determining the number of heaters required for a particular job, Electrothermal Engineering, Ltd., provide a comprehensive technical advisory service; they also publish an informative leaflet, No. 321, which not only details the method and sequence of operation, but includes a price list of heaters and ancillary equipment.

Electrothermal Engineering, Ltd., 270, Neville Road, London, E.7.

CO_2 Extinguisher

THE introduction of a leak-proof 10 lb. carbon dioxide fire extinguisher, Model 1510, is announced by Nu-Swift, Ltd. The result of three years experiment, the new model supersedes a similar Nu-Swift extinguisher of the same capacity, known as Model 1210. Mainly intended for fighting inflammable liquid fires, and fires involving electrical equipment, indoors, the new extinguisher has a 15 ft. range compared with only 8 ft. in the case of the old model. This, by preventing the fire fighter from getting burned, is an important feature. Additionally, by redesign of the nozzle, the fire fighting capacity of the extinguisher has been doubled, the new model being capable, in the hands of an experienced fire fighter, of putting out an 18 sq. ft. inflammable liquid fire. Carbon dioxide, although much less efficient for fire fighting than dry powder, is non-damaging in use and leaves no residue, while the carbon dioxide can be made to penetrate into places otherwise inaccessible. Hence it is invaluable for fighting fires in laboratories, or fires involving fine chemicals or complicated electrical or electronic equipment.

The new extinguisher which, like all Nu-Swift models, is operated in the upright position by striking a knob, is approved by the Fire Officers' Committee, Ref. No. 104/10, and is available for immediate delivery in Britain or for export.

Nu-Swift, Ltd., Elland, Yorks.

Alloying Aluminium by Tablets

AN agreement has been concluded between Murex, Ltd., and a West German manufacturer for the production and sale in the U.K. and the Commonwealth of alloy tablets based on manganese, chromium, titanium, antimony, copper, etc. The chief function of these tablets is to provide the aluminium industry with a more satisfactory and economic means of introducing alloying elements directly into aluminium alloys, by eliminating the " hardener " stage altogether.

The manufacture of aluminium hardeners is costly in time and money and frequently requires the use of temperatures considerably in excess of the melting point of the alloy, in order to ensure complete solution of the alloying element. This, in turn, leads to melting losses of the aluminium and/or the alloying element. In addition, undesirable contamination in the form of oxides and gases occurs. Even if such disadvantages could be discounted, the fact remains that the alloying element is only a small proportion of the hardener, and the remaining balance of aluminium has to be melted twice, once in the production of the hardener and again when the final alloy is being manufactured, necessitating additional fuel and labour costs.

It is claimed that, not only are the undesirable aspects of hardeners eliminated by the use of alloy tablets, but many positive advantages are gained. With a few exceptions the tablets are self-sinking and, therefore, do not need mechanical aids such as plungers. Slight turbulence caused by the tablets going into solution leads to a homogeneous distribution of the alloying element, at the same time enabling such elements already present to be more thoroughly distributed.

The holding time required to allow the element to go into solution is cut down to a very short period, and thus labour and fuel costs are reduced with the complementary advantage of enabling increased production to be achieved from a single furnace unit. Because of the very short holding time and the fact that the tablets create slight turbulence when going into solution, it is found that little or no mechanical stirring is necessary. This means that dross is virtually eliminated, whereas it is not possible to prevent dross formation with conventional " hardener " melting. No additional heating is required to put the element into solution, since the tablet is exothermic in its action, and up to 100% recovery of the alloying element can be expected. The cleansing and grain refining properties of the tablets are considered, by some users, to be the prime advantages, and the removal of contaminants results in improved flowability and castability.

The element concerned is incorporated in the tablets to give a fixed weight of useful content, which makes the

weighing and observation of changing composition unnecessary. The form in which the element can be added and the speed of solution enables final corrections to analysis to be achieved easily.

Alloy tablets are finding rapidly increasing application in European non-ferrous melting plants and it is generally appreciated that they can contribute considerably to the industry, by way of economies in time and fuel costs, providing at the same time a more flexible process which can be readily worked by unskilled operatives.

Murex, Ltd., Rainham, Essex.

Marikor Core Oil

MARIKOR is a special core oil which has been developed to meet the requirements of the foundry industry. It is available from Charles H. Windschuegl Ltd., who are also importers of Marinol K, of which Marikor is a derivative. Marikor is free from unpleasant odour and has been proved efficient and economical in actual foundry tests. The wetting properties are said to be excellent, and the rate of output of the cores is high because of easy working. The finished core breaks cleanly away from the casting, thus minimising the time lost on removing waste pieces. The core, when moulded, has the requisite "green strength," and bakes hard to give a "dry strength" exceeding 90 lb./sq. in., with satisfactory permeability. The oil is used in the orthodox manner. Moistened silicate sand should be used in the ratio of approximately 50:1 on the oil content, together with a little dextrin or similar binding agent to impart "green strength."

Charles H. Windschuegl, Ltd., 1, *Leadenhall Street, London, E.C.*3.

Mercuryless Diaphragm Instruments

GEORGE KENT, LTD., announce the addition to their Commander range of the new Kent-Barton mercuryless diaphragm instrument for the measurement of differential pressures in six maximum ranges, and up to 2,500 lb./sq. in. working pressure. These instruments, available intrinsically as circular-chart recorders, sector-scale indicators and circular-scale indicators, incorporate the "Barton" patented rupture-proof differential unit, which, although employing sensitive bellows for its actuating element, may be subjected to pressure differences equivalent to the pressure rating of the instrument without damage. Full line pressure can be applied across the bellows unit in either direction without damage—irrespective of the differential-pressure range of the instrument—owing to the valve in each bellows.

The torque-tube drive for conveying bellows movement to the instrument-index mechanism is leakage-free and requires no periodic lubrication, being virtually frictionless for the life of the instrument. Only the bellows exteriors are exposed to the metered fluid, and the unit is therefore completely self draining or venting; is without pockets to trap condensates and sediment formations; and has no small tubes or other restrictions to interfere with its function.

To these recorders and indicators for flow, level, specific gravity, etc., can be added—with certain limitations—additional measuring elements for pressure (Bourdon tube) and/or temperature (mercury-in-steel); also air-operated automatic control or transmission of the primary variable by incorporation of one of the new

Kent Mark 30 series of units. Other optional instrument functions are integration of rate of flow and, for recorders, crescent-scale indication. All Kent-Barton instruments offer the same user-advantages inherent in other Commander instruments, the most notable advantages being standardisation of parts and interchangeable-unit construction.

George Kent, Ltd., Luton, Beds.

Ceramic Coatings on Metals

HUNDREDS of components are at present being made in other less suitable materials because they are either too large, too complex, or too small in cross section to be made in solid ceramic. The United Insulator Division of The Telegraph Condenser Co., Ltd., have now developed a method of applying coatings of ceramic materials on metals, glass, and even plastics, in which the ceramic material is specially prepared, then heated to a temperature in excess of 1,650° C., and applied at high pressure to the part to be coated which is kept cool. The coating thickness can range from a few thousandths of an inch to 20 mm., or more. The coating used is chosen according to surface requirements, which may involve protection from abrasive wear, electrical insulation, heat insulation, or special use of dielectric properties.

The new coatings are being marketed under the trade name Unikote, and possible applications include thermocouple sheaths, heater supports, crucible and ladle linings, heater formers, induction heating coils, etc.

United Insulator Division, The Telegraph Condenser Co., Ltd., Oakcroft Road, Chessington, Surrey.

Inexpensive Copier

KODAK, LTD., have recently introduced the Verifax Signet copier, which has the versatility and many of the advantages of the existing Verifax copier but costs only £69. It makes perfect, permanent photo-accurate facsimiles of any document, whether written, drawn, printed or typed, single or double-sided; three copies can be produced in less than a minute and further copies are available withing seconds from the same matrix.

The copies, which are permanent, are produced dry and ready for immediate use. Translucent master copies for dye-line and blue printing can also be made quickly and easily. The copier is extremely simple to operate, and it is silent and clean in operation.

Kodak, Ltd., Kodak House, Kingsway, London, W.C.2.

New Design Centre Drill

THE Balfour Spirocentre drills, which are supplied 60° included angle of countersink, in the size range B.S.1 to B.S.7, and 3½ mm. to 18 mm., inclusive, were designed to overcome the inconsistencies so common with the usual pattern straight fluted combined centre drill and countersink. The new type gives greater accuracy with improved finish, and has free cutting properties resulting from positive rake. Furthermore, there is uninterrupted and easier chip clearance from a wider and less acute flute design, and breakages are cut to a minimum because of reduced operating pressure.

Arthur Balfour and Co., Ltd., Capital Steel Works, Sheffield.

Flow Recorder

THE new Arkon Model 1602 flow recorder has been specifically designed to meet the growing demand for a recorder suitable for the measurement of high pressure gas, compressed air, steam, water and other liquids. It embodies the simple design, and robust construction common to all Arkon recorders, making it ideally suitable for continuous operation under the difficult conditions often met with in gas works, steel works, foundries, etc.

The instrument uses the well-established principle of mercury U-tube and float, overload protection being incorporated. The recorder is fitted with a dual valve (instead of the three-cock assembly usually met with in this type of recorder) which incorporates automatic equalising. These features eliminate the possibility of mercury being blown into the impulse lines due to incorrect operation of valves or surges of pressure. The operating valves are inside the recorder case and accessible from the front of the instrument.

The Model 1602 has been provided with a chart which is very easy to read. It is rectangular, ruled in straight lines and is 6 in. high. The visible width of the chart covers 16 hours, making it easy to follow the record over the whole of a normal shift. A roll of chart lasts six weeks, and may be left on the rewind roller for as long as a week, or cut off daily or as required. The free end of the chart can be left to travel over the chart plate as it is picked up automatically on the collecting spool. This saves much time where charts are collected daily and also prevents irritating breaks in the record through failure to reset the chart correctly.

Where the instrument is required to total the flow automatically, an electrically operated integrator can be fitted as an optional extra. Charts can be supplied to reading in cubic feet per hour, gallons per hour, pounds per hour, inches w.g., differential pressure, or any units to meet users' requirements.

Walker, Crosweller & Co., Ltd., Cheltenham.

Preformed Spectroscopic Electrodes

UNION CARBIDE INTERNATIONAL CO., (Division of Union Carbide Corporation) has expanded its line of high-purity preformed electrodes through the addition of 12 new items, bringing the total to 52 different sizes and shapes. Included in the new items is an assortment of preforms in the ⅛ in. (3·2 mm.) diameter size which is becoming increasingly popular. Special shapes machined to customers' specifications can also be obtained. Because spectroscopic electrodes are used in detecting quantities of materials as small as one ten-millionth of a gram, extreme care is exercised throughout the manufacture of high-purity graphite spectroscopic electrodes. Not only must the electrode be made in a very pure state, it must be kept pure prior to its use. Accordingly, National spectroscopic electrodes are packed in practically a hygienic condition to help safeguard their purity. The air supply to the room is filtered, and the temperature and humidity closely controlled.

Carbon Products Department, Union Carbide International Co., 30 East 42nd Street, New York 17, N.Y., U.S.A.

Electronic Potentiometers

THE new Electroflo electronic potentiometer is a high-speed, continuous-balance, null-type instrument designed to register low potential electrical values from signal sources such as thermocouples, resistance thermometers, flow meters, strain gauges, shaft position indicators, etc. The potentiometer is available as a single point recorder; a recorder with multiple alarm switching; a controller-recorder with two-step or proportional action; and as a recorder-converter with pneumatic transmission signal of 3–15 lb./sq. in. It is claimed to be the simplest mechanism yet achieved in industrial potentiometer design, for the total motion is exercised through a single shaft which is mounted in ball races and the recording pen and indicating pointer as well as the control and multiple alarm switching, proportional sender, pneumatic converter and coding number are directly and positively related. Both the desired value indicator and the measured value pointer are readily observed from a distance. The new instruments are featured in Electroflo Publication No. 197.

Electroflo Meters Co., Ltd., Abbey Road, Park Royal, London, N.W.10.

CURRENT LITERATURE

Book Notices

THE DEVELOPMENT OF THE STEEL INDUSTRY

Planning No. 428. One of a series of broadsheets published by Political and Economic Planning, 16, Queen Anne's Gate, London, S.W.1. 16 pp. 2s. 6d.

THIS publication brings together the basic economic issues facing the steel industry—" no matter who owns it and whatever form of supervision is employed." These issues are the planning of steel capacity five or more years ahead ; the relation of pricing policies and decisions about location to the planning of development ; and the impact of a possible European Free Trade Area on the British steel industry.

The third development plan published in 1957 assumed industrial production would show an average gain of 3·75% per annum compound between 1954 and 1962 ; but the first half of this period has seen a rate of growth of little more than 1% per annum. This slow expansion of the economy has caused the wisdom of present development plans to be doubted. Long debates have taken place on the timing and location of the fourth strip mill, now settled by the Government's decision to proceed in the present planning period, but to have initially two smaller developments instead of one large one.

Most home steel sales are subject to maximum prices laid down by the Iron and Steel Board, the official advisory body which is also responsible for ensuring adequate development. The Board's pricing policy has changed somewhat during the last two years or so. Prices now allow for " reasonable capital charges at new plants," in addition to production costs. Such charges are higher, but production costs presumably lower, than at old plants. It is hoped this new pricing policy " will have helped to maintain companies' will to invest during the recession through which the industry is now passing." Britain, like the U.S., has maintained stable steel prices, while the European Coal and Steel Community has allowed more flexibility, particularly in export markets.

Comparing British with Continental producers with whom there would be more competition in a European Free Trade Area, P.E.P. says : " The British steel industry is now on roughly equal terms as far as the cost of materials, fuel and labour is concerned. The general standard of technical and managerial efficiency is now very high, and this may prove important in an intensified struggle for markets." The main benefit of a F.T.A. would probably be indirect, through increased opportunities for the steel-using industries. One of the main results of formal British association with the European Coal and Steel Community has been to bring our steel tariff down to 10% and into line with that of E.C.S.C.

Britain has at present cost advantages over the E.C.S.C. countries in plates, sheet and tinplate, and is least competitive in light hot rolled bars and sections. In the event of a F.T.A., more Continental competition may be expected in Southern England, which consumes about 30% of national usage but has no major steelworks. British plants near deep-water harbours may, however, expand sales in parts of the Continent.

As the conclusion points out : " The development of the European Economic Community and the possible association of Britain with it in a F.T.A. will affect decisions about the capacity and location of the British industry, and in particular the question of the acceptance of some imports as against the objective of national self-sufficiency in steel."

THE EFFICIENT USE OF FUEL

Second edition, pp. vi + 888. H.M. Stationery Office, London, 1958. 35s. (by post 37s.).

THE second edition of " The Efficient Use of Fuel " has been completely revised in detail and so largely rewritten that it is practically a new work. Its preparation has been carried out by leading fuel engineers and fuel technologists working under the control of the Fuel Efficiency Education Committee of the Ministry of Power.

The new edition incorporates the results of developments in the science and practice of fuel technology over the past fourteen years. The chapters on Heat Transmission, The Flow of Fluids, Water Treatment, Space Heating, Drying and Conditioning, Heat Balances, and Instrumentation have been almost completely rewritten, and that on Coal largely rewritten and brought up to date with reference to the National Coal Board's Code Number Classification. Callendar's Steam Tables replace those of Keenan and Keyes, in which respect the new edition is now in accord with the companion volume " The Efficient Use of Steam." The results of the work of the British Standards Institution Committees on Sampling and Analysis of Coal and Coke have been used in revising the appropriate chapters.

Among other new features are a comprehensive bibliographical reference list after each chapter, a 2-colour " throw-out " psychrometric chart and an appendix of Units and Conversion Factors.

Trade Publications

DURING the past decade, Dorman Long & Co., Ltd., have spent something like £60 million on development and the illustrated brochure " Dorman Long 1958 " depicts the three stages in which the development programme was carried out, beginning with the reception, handling and preparation of the raw materials for the blast furnaces, continuing with the erection of the Lackenby steel plant, and culminating with the third stage, which comprised several major projects, including the two large blast furnaces at Clay Lane and, by far the greatest in magnitude and interest, the universal beam and heavy section mill at Lackenby.

SKLENAR reverberatory melting furnaces have been in use in Britain and many overseas countries for almost thirty years. These furnaces have a high thermal efficiency, and as very little heat is radiated the working conditions are comfortable. Melting and labour costs are low, and charging times are eliminated in the normal sense, as the furnaces melt at the same time as they are being charged. These and other advantages claimed for Sklenar furnaces are discussed in a new booklet, " Effici-

ency in Melting," issued by Sklenar Furnaces, Ltd., 385, Newport Road, Cardiff, in which the standard units made by the Company are illustrated.

We have received from Cambridge Instrument Co., Ltd., two new publications. List 144/C describes a range of indicators, recorders, and controllers for use with Cambridge automatic gas analysers of the thermal conductivity type. It also includes details of units for the supply and standardisation of the katharometer-bridge current. The latest edition of the Cambridge list of vapour pressure thermometers (307/2) has been printed in a more convenient form to facilitate selection of suitable patterns and ranges.

Johnson, Matthey & Co., Ltd., have produced a new publication, 1700—Platinum Laboratory Apparatus, that revises and combines the earlier booklets 1710 and 1720. This publication makes a comprehensive survey of the platinum laboratory apparatus and electrodes in the JMC range, and includes useful advice on care and maintenance.

The first of a new series entitled *Die Casting News* has been published by the Zinc Alloy Die Casters Association, an affiliated member of the Zinc Development Association. It is an eight-page bulletin containing information, with photographs, on up-to-the-minute applications of zinc alloy die castings. All the parts have been chosen to illustrate particular advantages of die casting in zinc alloy, such as the ability to produce complex shapes in one fast operation, the elimination of laborious time-consuming machining, and the ease with which fastening devices, bearings, etc. can be cast-in. In addition to these functional assets, the fine smooth finish of zinc die castings enables a highly decorative finish—enamel or chromium—to be easily applied, and examples in this issue include car trim, a parking meter, and industrial scales. These bulletins will be distributed widely to designers, production engineers, and potential users. Copies are available free on request from the Zinc Development Association, 34, Berkeley Square, London, W.1.

I.C.I. has for many years been producing a standard range of open-topped metal degreasing plants operating on trichloroethylene. Ever since about 1930 the Company has also produced to special order enclosed plants equipped for mechanical handling of the work during the degreasing cycle—indeed a number of plants capable of fully automatic working have been produced. A new leaflet "Trichloroethylene Degreasing Plant Type E," has recently been issued to introduce a standard range of totally enclosed mechanised plants. The work handling capacity of the new plants and the choice of treatments available is sufficiently flexible to enable them to deal with a wide variety of industrial metal degreasing problems. This new development will eliminate the intricate design work entailed in preparing a plant and ensure quicker delivery.

The problem of aerodynamic heating is one with which the designer of high-speed aircraft is permanently confronted. With the advent of supersonic aircraft a solution to the problem is being sought in the use of ultra-high-strength nickel-containing steels or alloys for the relevant airframe components. This trend is reflected in a number of the papers abstracted in the November issue of *The Nickel Bulletin*. Reference is made, for example, to papers reporting investigation of the thermal properties of Inconel and other high-nickel alloys; the high temperature tensile, compressive and shear properties of precipitation-hardenable stainless steels; the corrosion-resistant characteristics of such steels; and aeronautical applications of high-nickel alloys. Other items in the section relating to heat- and corrosion-resisting materials cover various aspects of the physical metallurgy of turbine-blading alloys. The same section contains references to a comprehensive review of the welding of stainless steels; to reports giving details of techniques developed for diffusion bonding and brazing nickel-containing materials; and to the cause of porosity in high-nickel-alloy welds. The advantages derived from the use of Monel in the petrochemical industry are considered, and allusion is made to the resistance of nickel-containing materials to various corrosive media.

Books Received

"Cast Tools." By Z. Eminger and V. Koselev. 230 pp. inc. numerous illustrations. London, 1958. Constable & Co., Ltd. 20s. net.

"Cores and Core-Making." By F. D. Roper. 125 pp. inc. index. London, 1958. George Allen & Unwin, Ltd. 21s. net.

"Technology of Colombium (Niobium)." Edited by B. W. Goner and E. M. Sherwood. Papers presented at the symposium on columbium (niobium) of the Electrothermics and Metallurgy Division of the Electrochemical Society, May 1958, at Washington, D.C. 120 pp. New York and London, 1958. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 56s. net.

"The Directory of Opportunities for Qualified Men, 1959." With a preface by Sir Miles Thomas. 116 pp. London, 1958. Cornmarket Press, Ltd. 8s. 6d. net; by post 9s. 2d.

16th International Congress of Pure and Applied Chemistry, Paris 1957. Papers presented to the Section on Mineral Chemistry. 891 pp. London, 1958. Butterworths Scientific Publications (Publishers to the International Union of Pure and Applied Chemistry). 97s. 6d.; by post 2s. 6d. extra.

Höganäs Iron Powder Handbook. Vol. 1: Basic Information. Sweden, 1958. Hoganas-Billesholms AB.

"The Solid State for Engineers." By M. J. Sinnott. 522 pp. inc. index. New York and London, 1958. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 106s. net.

"Effect of Surface on the Behaviour of Metals." Lectures delivered at the Institution of Metallurgists' Refresher Course, 1957, by G. L. J. Bailey, T. P. Hoar, F. T. Barwell and R. W. B. Stephens. 100 pp. London and New York, 1958. Published for the Institution of Metallurgists by Iliffe and Sons, Ltd., and the Philosophical Library. 21s. net. By post 10d. extra.

"Metallurgical Thermochemistry." Third edition revised. By O. Kubaschewski and E. Ll. Evans. International Series of Monographs on Metal Physics and Physical Metallurgy, Vol 1. 426 pp. inc. name and subject indexes. London, 1958. Pergamon Press. 63s. net.

INDUCTION HEATING SUPREMACY 2000

Birlec-Efco (Melting) Limited has been formed by Birlec Limited and Efco Limited for the design and supply of all types of electric melting furnaces, including vacuum furnaces, for the ferrous and non-ferrous metals industries, together with smelting furnaces and induction heating equipment. During the last 50 years the parent companies have installed throughout the world:—

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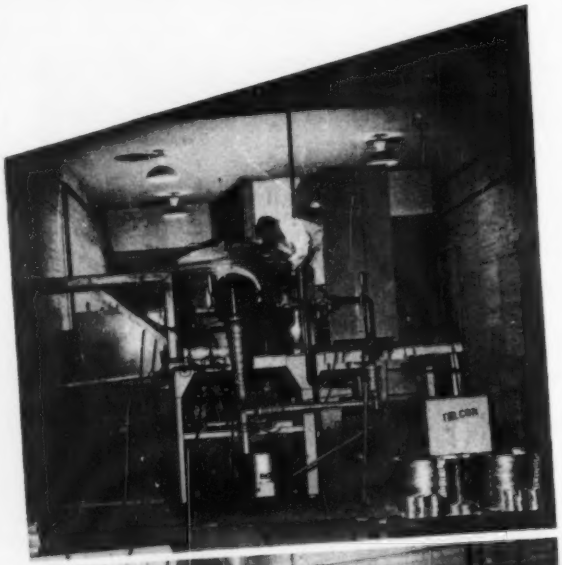
*VACUUM FURNACES



(Top) **Vacuum melting Telcon "Mumetal" magnetic materials.**

By courtesy of The Telegraph Construction and Maintenance Co. Ltd.

(Below) **Efco-Edwards 56lb. vacuum melting and casting furnace for the production of special vacuum steels and alloys.**

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LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
JANUARY, 1959 Vol. LIX, No 351

The Rapid Determination of Beryllium Oxide in Beryllium Metal

By A. R. Eberle and M. W. Lerner

U.S. Atomic Energy Commission, New Brunswick Laboratory, New Brunswick, New Jersey

A rapid method of determining beryllium oxide in beryllium metal is presented. Samples of vacuum-cast or thermal-reduction metal powder or fine chips are dissolved in a methanol-bromine solution. Dissolution of resistant particles is completed by a methanol-hydrochloric acid solution. Electrolytic metal samples require a preliminary heat treatment before dissolution. Beryllium oxide in the undissolved residue is determined colorimetrically or volumetrically. Conditions were chosen to yield the same results as those obtained with the hydrogen chloride volatilization method.

THE oxygen content of beryllium metal has been determined by several methods: vacuum fusion[1,2]; chlorine[3] or hydrogen chloride volatilization[4]; radioactivation[5]; selective dissolution with hydrochloric acid[3] or copper sulphate solution.[6] In developing the radioactivation method, Osmond and Smales[5] compared most of these methods, including a hydrogen evolution procedure.

Generally, hydrogen evolution methods are inherently subject to error. The other methods, with the exception of the selective dissolution techniques, require either considerable care in manipulation or elaborate equipment. Both selective dissolution methods are simple, but in our experience all efforts to speed up the hydrochloric acid procedure, which requires a long digestion period, have led to low results. On the other hand, the more rapid copper sulphate method of Wallace has given results generally high. This method has two undesirable features: the dissolution is accompanied by the accumulation of large quantities of metallic copper, and, as a result, the completion of the reaction is difficult to determine when powdered samples are analysed; the presence of beryllium carbide may lead to high results.

In the present investigation, it was felt that any new method developed must meet three requirements: (1) it must be rapid and lend itself to multiple determinations; (2) it must yield results comparable to the fairly reliable hydrogen chloride volatilization procedure; and (3) it must be simple enough for routine performance by inexperienced technicians.

The method proposed is based upon the determination of oxide in aluminium by selective dissolution of the metal in a solution of bromine in methanol.[7-10] The beryllium oxide in the undissolved residue is analysed for beryllium by the conventional *p*-nitrobenzeneazoorcinol procedure.[11] While the procedure as developed is empirical in nature, it should find considerable use in laboratories required to carry out large numbers of routine analyses for specification purposes.

As an alternate method of analysing the beryllium in the residue, the convenient volumetric determination as carried out by Wallace[6] was used in a few instances. Although this procedure appeared to be promising in that it further shortened the overall procedure, it was not fully evaluated.

Equipment

Apparatus

Spectrophotometer—Beckman Model DU quartz spectrophotometer, 2-cm. cells.

Centrifuge

Centrifuge Tubes—Graduated, Pyrex, 50-ml. capacity.

Crucibles—Gooch-type fritted glass, Pyrex, fine porosity, 15-ml. capacity.

Reagents

All reagents, unless otherwise stated, are reagent grade, purity beryllium metal in hydrochloric acid and dilute

Standard Beryllium Solution—Dissolve 1·000 g. of high- to 1 litre. Dilute 10·0 ml. of this stock solution to 500 ml. to obtain a standard solution of 20 μg. per ml.

p-Nitrobenzeneazoorcinol Solution—Dissolve 24·0 g. of sodium hydroxide and 18·0 g. of boric acid in water and dilute to 1 litre. Transfer the solution to a 2-litre beaker and add 75 mg. of *p*-nitrobenzeneazoorcinol. Stir mechanically for 2 hours and filter. Store in the dark.

Methanol—Use material with a water content not exceeding 0·1%.

Methanol-Hydrochloric Acid Solution—Prepare just before using by diluting 40 ml. of concentrated hydrochloric acid to 500 ml. with methanol.

Aluminium Solution—Dissolve 34·8 g. of aluminium nitrate nonahydrate in water and dilute to 500 ml.

Nitric Acid—Concentrated.

Sulphuric Acid—Concentrated and 0·05N.

Sodium Hydroxide—0·05N.

TABLE I.—SOLUBILITY OF BERYLLIUM OXIDE IN METHANOL-BROMINE.

Reflux Time (hr.)	BeO Dissolved (mg.)		
	500° C. Treatment	800° C. Treatment	1,000° C. Treatment
1	0·20	0·05	0·008
2	0·29	0·05	0·013
3	0·44	0·13	0·028
4	—	0·20	0·050
5	0·81	0·24	0·057

Phenol Red—0·1%.
Bromine
Ammonium Chloride.

Procedure

High-Temperature Metal (Vacuum-Cast or High-Temperature Reduction).

Place a 0·5-g. sample of powder or fine chips in a dry 250-ml. extraction flask. Add 10 ml. of methanol. Add *slowly*, in 2- or 3-ml. portions, 50 ml. of methanol containing 3·0 ml. of bromine. (The reaction is very vigorous and should be carried out in a well ventilated hood). When all particles of the metal appear to be dissolved, add 50 ml. of the methanol-hydrochloric acid solution. Mix the contents by swirling every few minutes over a period of 30 minutes. Transfer the solution to a 150-ml. beaker and wash any residue from the flask into the beaker with methanol. Filter the solution with vacuum through a 15-ml. glass-fritted crucible. (Some crucibles of fine porosity filter more rapidly than others. Use the more rapid-filtering crucibles). Wash the residue and crucible with methanol until the wash is free of bromine colour. Remove the crucible from the filtering flask and wash the bottom and outside of the crucible with water.

Transfer the crucible to the 150-ml. beaker and add 15 ml. of concentrated sulphuric acid and 10 ml. of concentrated nitric acid. Cover the beaker with a watch glass and dissolve the residue by heating on a hot-plate until fumes of sulphuric acid evolve. Cool the solution and dilute with 100 ml. of water. Transfer the solution to a 500-ml. volumetric flask. Wash the crucible and beaker twice with 100-ml. portions of hot water, adding the washings to the volumetric flask. Dilute the solution to 500 ml.

Into four of five 50-ml. centrifuge tubes add, respectively, 0, 1·00, 3·00 and 5·00 ml. of the standard beryllium solution. Add 20 ml. of 3% sulphuric acid to each tube. To the fifth tube add 20·0 ml. of the sample solution. To all tubes add 1·0 ml. of the aluminium nitrate solution and about 2 g. of solid ammonium chloride. Dilute each tube to about 35 ml. with water. Stir the sample and standard solutions with glass rods and precipitate the aluminium and beryllium by the addition of 5 ml. of concentrated ammonium hydroxide. Stir thoroughly and remove the glass rods. Centrifuge the suspensions and carefully decant the supernatant liquids. Drain the tubes by standing them inverted on a dry towel for about 5 minutes. To each tube add 20·0 ml. of the *p*-nitrobenzeneazoorcinol reagent and disperse the hydroxides in the solution by stirring with the glass rods. Warm the solutions in a water bath at 80°–90° C. for 5 minutes. Cool to room temperature. Transfer the solutions to 50-ml. volumetric flasks and dilute to volume.

Measure the absorbance of each solution at 520 mμ in 2-cm. cells. Use the solution containing no beryllium as a reference. Since Beer's law is not obeyed, draw a smooth curve through the plot of absorbance versus concentration of the standards. Calculate the beryllium oxide content by the following equation :

$$\% \text{ BeO} = \frac{\text{Be (in } \mu\text{g.)} \times 0{\cdot}0069}{\text{Sample Weight (in g.)}}$$

Determine the standard curve with each set of samples analysed, since the *p*-nitrobenzeneazoorcinol reagent slowly precipitates upon standing. Filter the solution if it appears turbid when examined in a strong light.

Low-Temperature Beryllium (Electrolytic)

Place a 1-g. sample in a platinum boat. Insert the boat into a small combustion tube (Pyrex may be used) and sweep out the tube with helium from which oxygen is removed by a hot copper train. Heat the tube for 1 hour at 200° C. to remove moisture. Over a period of 30 minutes, raise the temperature to 600° C. and retain at this temperature for 30 minutes. Cool the tube to room temperature under helium. Weigh out a 0·5-g. sample and proceed as described above for high-temperature metal.

Alternate Method of Analysing the Residue

After dissolution of the sample, add a Whatman Filter Accelerator to the solution and filter with vacuum through a 9-cm. Whatman No. 42 paper. Wash the paper with methanol until no trace of yellow colour remains.

Transfer the paper to a 100-ml. platinum dish. Add 40 ml. of water and 0·5 g. of sodium fluoride. Evaporate to near dryness on the steam bath. Add 25 ml. of water and transfer the solution and filter paper to a polyethylene beaker. Add 2 drops of phenol red solution and 10 ml. of 0·05N sulphuric acid. Back-titrate with the 0·05N sodium hydroxide. Carry out a blank determination.

Calculate the amount of BeO from the relationship :

$$\text{BeO} + 4\,\text{NaF} + \text{H}_2\text{O} \longrightarrow \text{BeF}_4^{--} + 4\,\text{Na}^+ + 2\,\text{OH}^-$$

1 ml. of 0·05N sodium hydroxide being equivalent to 0·625 mg. of BeO.

TABLE II.—EFFECT OF REFLUX TIME IN METHANOL-BROMINE ON APPARENT OXIDE CONTENT.

Sample	BeO by Hydrogen Chloride Volatilization (%)	Hours Refluxed					
		0·0	0·5	1·0	2·0	3·0	4·0
		Apparent BeO (%)					
NBL-8017 (high-temp. reduction)	1·18 ± 0·01	2·89	—	1·63	1·54	1·43	1·38
NBL-D1663 (vacuum-cast)	0·52 ± 0·04	1·64	—	—	—	0·69	0·67
NBL-D869 (vacuum-cast)	0·59 ± 0·01	3·05	1·42	1·06	—	0·82	0·82
NBL-D1194 (vacuum-cast)	0·58 ± 0·06	1·66	—	0·70	—	0·60	0·64
NBS-BF (electrolytic)	4·23 ± 0·18	3·90	3·03	2·71	2·35	1·99	1·87

Experimental

Solubility of Beryllium Oxide

Thorpe[12] summarised the general chemical reactivity of beryllium oxide by stating, in effect, that the ease of attack on the oxide by acids and alkalis depends upon the temperature to which the oxide has been subjected. In Table I are given the solubilities in methanol-bromine of oxide prepared from freshly precipitated hydroxide calcined at various temperatures. The oxide, 20 mg.,

was refluxed in 100 ml. of methanol containing 4 ml. of bromine for periods ranging from 1 to 5 hours. After filtration, the total oxide dissolved was determined colorimetrically.

The solubilities were also determined under the conditions of the proposed procedure. The oxide, 20 mg., was refluxed for 5 minutes with 60 ml. of methanol containing 3 ml. of bromine, and then 50 ml. of the methanol-hydrochloric acid solution was added. The mixture was agitated for 30 minutes. After filtration, the oxide dissolved was determined as before. With oxide calcined at 500°, 800° and 1,000° C., the quantities of oxide dissolving were 0·18, 0·021 and 0·017 mg., respectively.

These results indicate that the solubility loss may be held down to insignificant values if the oxide is prepared at 800° C. or higher. On the other hand, serious loss can be expected if the oxide is heated to 500° C., or below. In practice, it was found that heat treating the metal to only 600° C. ensured the comparative insolubility of the oxide. Heat-treatment of electrolytic metal at 600° C. was, therefore, used to convert the oxide to the "insoluble" state.

Bromine Concentration

If it is assumed that the reaction of bromine in methanol with beryllium proceeds in the following manner:

$$2\,Be + Br_2 + 2CH_3OH \rightarrow BeBr_2 + Be(OCH_3)_2 + H_2$$

(with the possibility of addition-compound formation to give $BeBr(OCH_3)$)[7], the stoichiometry requires approximately 1·5 ml. of bromine for 0·5 g. of metal. When these quantities are used, essentially all of the metal dissolves with the evolution of hydrogen. No attempt was made to identify the beryllium product and, therefore, the question of the reaction mechanism still exists. In the proposed procedure, it was decided to use 3·0 ml. of bromine, approximately twice the stoichiometric quantity, per 0·5 g. of metal. The effect of higher concentrations was not studied.

Necessity for Hydrochloric Acid Treatment

From the analyses of samples on which the oxide content had previously been determined by the hydrogen chloride volatilization method, it was found that with high-temperature metals simple dissolution in methanol-bromine generally led to high results. Apparently these metals contain small particles of metal coated with oxide and resistant to attack by the methanol-bromine solution. Even after 4 hours of refluxing, these particles are not completely dissolved (Table II). For electrolytic metals, simple dissolution without refluxing yields the approximately correct oxide values, while refluxing results in progressively increasing losses of beryllium oxide.

To dissolve these resistant particles selectively, the additional treatment with hydrochloric acid-methanol solutions was studied. The results in Table III were obtained by reacting 0·5-g. samples in 10 ml. of methanol with 50 ml. of methanol containing 3·0 ml. of bromine. After all visual reaction had occurred, 50 ml. of methanol containing from 4 to 10% (v/v) of concentrated hydrochloric acid was added, and the contents were mixed by frequent swirling for 30 minutes. After filtration, the residues were analysed for beryllium. It can be seen from Table III that the methanol containing from 6 to 8% (v/v) of concentrated hydrochloric acid apparently dissolves these resistant particles selectively.

TABLE III.—EFFECT OF ADDING HYDROCHLORIC ACID-METHANOL ON APPARENT OXIDE CONTENT

Sample	BeO by Hydrogen Chloride Volatilization (%)	Percentage of Hydrochloric Acid (v./v.) in the added 50 ml. Acid-Methanol Mixture						
		4·0	5·0	6·0	7·0	8·0	9·0	10·0
		Apparent BeO (%)						
NBL-8017 (high-temp. reduction)	1·18 ± 0·01	1·32	1·22	1·18	1·18	1·17	1·13	1·10
NBL-5370 (vacuum-cast)	1·05 ± 0·07	1·27	1·16	1·07	1·05	1·04	0·94	0·91
NBL-D1663 (vacuum-cast)	0·52 ± 0·04	0·69	0·62	0·55	0·52	0·50	0·48	0·45

Effect of Water in Methanol

The effect of water in the methanol used to make up the methanol-bromine solution was studied by reacting 0·5-g. samples with 100 ml. of methanol containing different amounts of water plus 3 ml. of bromine (Table IV). With increasing water content of the methanol, the reaction becomes more incomplete. At 0·5% water, the error becomes serious. The water content of the methanol used in this investigation and obtained in drum quantities did not exceed 0·1%.

Effect of Presence of Beryllium Carbide

Beryllium carbide appears in many forms,[4] depending upon the method of production. The reactivity varies to such a degree that some forms are attacked by atmospheric moisture while others are resistant to attack by cold concentrated acid. Although a sample of carbide, kindly supplied by Brush Beryllium Company, was found to be resistant to the methanol-bromine solution, partial proof of the non-interference in the proposed procedure of carbide in samples of beryllium has been obtained.

With the exception of the electrolytic sample, NBS-BF which contained 2,600 p.p.m. of carbon, the carbon content of the samples available was about 800 p.p.m. These values correspond to 1·08 and 0·33% of beryllium oxide if the carbide is not dissolved and subsequently shows up in the residue. The good agreement between the results obtained with the proposed procedure and the hydrogen chloride volatilization method, in which the carbide does not interfere, argues against the non-reactivity of the carbide if present as such.

Partial experimental proof of the dissolution by methanol-bromine of the carbon-containing compound in the metal was obtained by dissolving two 2-g. samples of metal containing 1,720 and 5,200 μg. of carbon, respectively. After dissolution, with no refluxing, 374

TABLE IV.—EFFECT OF WATER IN THE METHANOL-BROMINE ON THE APPARENT OXIDE CONTENT.

Percentage Water in the Methanol	Apparent BeO (%)
0·02	0·84
0·07	0·84
0·17	0·84
0·27	0·85
0·37	0·86
0·47	0·87
0·57	0·98
1·07	1·17
3·07	3·13
5·07	5·48

TABLE V.—COMPARATIVE RESULTS ON HIGH-TEMPERATURE METAL.

Sample	BeO (%) by		
	Hydrogen Chloride Volatilization	Methanol-Bromine Dissolution	
		Colorimetric	Volumetric
NBL-8107 (high-temp. reduction)	1·17	1·18, 1·15	0·84
NBL-5370 (vacuum-cast)	0·95, 1·06	1·04, 1·05	0·96
NBL-D869 (vacuum-cast)	0·58, 0·60	0·60, 0·61	—
NBL-D1194 (vacuum-cast)	0·64, 0·51	0·53, 0·53	0·48
NBL-D1663 (vacuum-cast)	0·57, 0·48	0·52, 0·50, 0·53	0·46

and 2,540 μg., respectively, of carbon were found in the residues. After 4 hours of refluxing, the carbon values of the residues decreased very little and the residues, the latter especially, appeared to contain free carbon. The carbon, therefore, apparently is present in the metal both as carbide and free carbon, neither of which interferes with the analysis.

It is of interest to report an experiment checking the validity of the statement that the carbide reacts with anhydrous hydrogen chloride in the volatilization method[13] according to the reaction :

$$Be_2C + 4\ HCl \longrightarrow 2\ BeCl_2 + CH_4.$$

A 200-mg. sample of carbide was treated with dry hydrogen chloride at 700° C. for 1·5 hours. The formation of beryllium chloride was clearly visible. The black residue, 83·1 mg., was found by ignition to contain 73·1 mg. of free carbon : beryllium oxide, 10·0 mg., remained after the ignition. If this oxide were produced solely from unreacted carbide, 6 mg. of carbide did not react with the hydrogen chloride. Thus, at least 189 mg. of carbide is accounted for. This recovery is increased if it is assumed that some of the oxide was present as such in the original sample. Moreover, a trace of free carbon was also blown out of the boat during the run. Accordingly, it is formulated that the reaction of beryllium carbide with dry hydrogen chloride proceeds as follows :

$$Be_2C + 4\ HCl \xrightarrow{700^\circ C.} 2\ BeCl_2 + C + 2H_2$$

with no methane production.

Results

Table V presents some typical analyses of high-temperature metals. The good agreement with the results obtained by the hydrogen chloride volatilization procedure is evident. Also shown in Table V are some results obtained by using the alternate volumetric method for determining beryllium in the residue after dissolution. This procedure makes the overall method very rapid, but the results can be seen to be slightly low.

In Table VI are presented the results obtained on a typical electrolytic metal analysed by four different methods : by the hydrogen chloride volatilization procedure ; by the procedure for high-temperature metal ; by the procedure for low-temperature metal ; and by the simple dissolution in methanol-bromine without previous heat treatment or methanol-hydrochloric acid treatment after dissolution. The latter two procedures can be seen to give results comparable to the hydrogen chloride volatilization procedure. Although some slight oxidation may occur during the heat treatment, this procedure is recommended for metals of this type, to avoid the possibility of high oxide losses in the dissolution step. It may prove advantageous to pellet powdered metals before heat treatment to reduce the surface area, and thereby keep any oxidation at a minimum.

TABLE VI.—COMPARATIVE RESULTS ON ELECTROLYTIC METAL SAMPLE NBS-BF.

Analytical Method	BeO (%)
Hydrogen Chloride Volatilization	4·36, 3·92, 4·17, 4·46
"High-Temperature Metal"	1·94
"Low-Temperature Metal"	4·29, 4·32
Simple Methanol-Bromine Dissolution	3·95, 3·90

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International Polarography Congress

THE Second International Congress of Polarography, organised by the Polarographic Society, will be held in the University of Cambridge from August 24th to 29th 1959, and will consist of scientific sessions (original papers, reviews and discussions), an exhibition of commercial equipment, demonstrations of laboratory apparatus, visits to local industry and places of interest, and social functions. A supporting programme for ladies is being arranged.

The scientific programme will be divided into the following sections : (1) instrumentation. (2) theory and kinetics, (3) analytical and industrial applications, (4) fundamental studies, (5) biological and medical applications, and (6) miscellaneous. There will also be four plenary lectures by world authorities and six section lectures. Contributions will be welcome and details should be submitted to : G. F. Reynolds, Esq., Chemical Inspectorate, Ministry of Supply, C.36. Royal Arsenal, Woolwich, London, S.E.18, England. Notification of intention to submit a communication should be made as soon as possible, and in any case not later than March 31st. 1959, by which date a summary not exceeding 200 words is also required. Preprints of all papers will be issued and final manuscripts must therefore be received not later than May 31st, 1959.

Requests for application forms and further details should be sent to : Mrs. B. Lamb, Chemistry Laboratory, Eversheds and Vignoles, Corner of Iveagh Avenue, North Circular Road, London, N.W.10. England.

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The Determination of Cadmium in Zinc Anodes

By W. C. G. Wheeler and D. Durant

(The Central Dockyard Laboratory, H.M. Dockyard, Portsmouth)

The cadmium, along with an appreciable amount of zinc, is removed as sulphide from sulphuric acid solution in a closed flask. The zinc is then removed as ammonium zinc phosphate and the cadmium in the filtrate is determined colorimetrically as the sulphide.

IN zinc anodes for cathodic protection in sea water, the zinc used, which must be of a high grade containing not more than about 0·25% of lead, is modified by the addition of small amounts of aluminium, cadmium and silicon. Aluminium counteracts the effect of traces of iron in cementing the corrosion product, and cadmium[1] apparently assists shedding of the soft corrosion product formed either in the virtual absence of iron—less than 5 p.p.m.—or when the effect of traces of iron has been neutralised by aluminium. If the iron content of the zinc stock is high, 30–150 p.p.m., treatment with silicon is also required.[2] Added as an alloy with the aluminium, it rises through the melt taking all but traces of the iron with it.

There are well known and relatively simple methods for the determination of lead and of aluminium, and a special method for determining iron has been suggested by one of us.[2] The purpose of this paper is to describe a method for separating and determining cadmium which is simpler and less tedious than the usual method.

Method

Special Reagents

5 N Sulphuric Acid—275 ml. of concentrated sulphuric acid diluted to 2 litres.

10% *Ammonium Phosphate Solution*—50 g. of dibasic ammonium phosphate, 35 g. of ammonium chloride, 50 ml. of 6 N (60%) hydrochloric acid, water to 500 ml.

Ammonium Chloride-Phosphate Solution—140 g. of ammonium chloride, 200 ml. of the above ammonium phosphate solution, water to 2 litres. The solution should be neutral to bromo-cresol purple.

Potassium Cyanide Solution—13 g. of potassium cyanide are dissolved in a litre of 10% caustic soda. This solution is stored in a polythene bottle.

Sodium Sulphide Solution—Pass hydrogen sulphide into 10% caustic soda until the solution contains over 3% of sulphur. The solution is stored in an aspirator fitted with a pyrogallol guard tube.

Separation of the Cadmium

Dissolve 5 ± 0·01 g. of the zinc in 50 ml., carefully measured, of cold 5 N sulphuric acid in a conical flask. To accelerate solution, add 5 ml. of a 0·1% solution of nickel sulphate crystals.[3] When action has entirely ceased, boil gently until there are no particles tending to float and no sign of effervescence, then add 5 ml. of N/50 nitric acid, or the equivalent, and boil for a few minutes. Dilute with cold water to about 100 ml. and stand until cold—overnight if lead is to be determined on this portion. Filter, washing with cold water. To the filtrate add 15 ml. of a 2% aqueous solution of thioacetamide, make up to 250 ml. and transfer to a half-litre, short neck, round bottom flask. Insert a bung fitted with a good tap, close the tap and stand the flask on a 3½ or 4 in. hole in the steam bath, swirling occasionally, until the supernatant liquid is clear.

The pressure and quantity of hydrogen sulphide and the concentration of acid (0·4 N) have been so adjusted that the solution clears in about 2 hours, with precipitation of about 0·2 g. of zinc sulphide, which is sufficient to ensure complete precipitation of the cadmium and is a very suitable amount for the next separation.

Filter, washing with hot water and leaving no water in the flask. Drain the stem of the funnel and wash the precipitate off the paper into a small beaker. Allow the precipitate to settle and pour the water through the paper, rejecting the runnings. Place 10 ml. of 3 N (30%) hydrochloric acid in the flask and warm on the steam bath to dissolve adherent sulphides. Empty the flask into the beaker, washing out with 30% hydrochloric acid. Warm to redissolve the sulphides and pour through the same paper, collecting the runnings in a 150 ml. beaker, marked at 40 ml. and at 75 ml. Wash with hot 30% hydrochloric acid. Use no water.

The amount of acid used should total 40 ml. Boil, without evaporation, to remove hydrogen sulphide, destroying the last traces by dropwise addition of bromine water until the colour persists. Add 10 ml. of the ammonium phosphate solution and almost neutralise with 6 N (about 35%) ammonia. At this stage the solution should measure about 75 ml. and will be approximately 2 N with respect to ammonium chloride. Heat to boiling, and to the vigorously boiling solution add 6 N ammonia, dropwise, to the first permanent precipitate. Continue boiling, when a coarse precipitate of zinc ammonium phosphate will be observed to increase in quantity. Continue to add the ammonia dropwise, at intervals, allowing each precipitate so formed to become crystalline, until a drop seems to produce no further precipitate, then rather more rapidly until a faint but unmistakable odour of ammonia persists. During this operation, maintain the volume with *boiling* water. At the first sign of bumping, if it occurs, transfer the beaker at once to the steam bath and complete the operations as described whilst stirring vigorously. Wash down the sides of the beaker with a fine jet using the minimum of water. Swirl gently to mix in the water, clean or change the cover glass and stand till cold. Filter directly into a 100 ml. graduated flask, washing with cold water. Make up to the mark with water.

It is surprising that this simple separation does not appear in the literature. It removes not only zinc but any traces of other metals which would affect the colour of cadmium sulphide in the presence of potassium cyanide.

Colorimetric Determination of the Cadmium

Transfer an aliquot to a 50 ml. stoppered cylinder, add 5 ml. of the potassium cyanide solution and make up to 50 ml. with the ammonium chloride-phosphate solution which, apart from the cadmium, has the same composition and strength as the liquid in the flask. Add one drop of the sodium sulphide solution, mix gently and read the colour immediately in a photoelectric absorptiometer using 2 cm. cells and Spectrum Violet 601 filters. It is not difficult to take the reading within 45 seconds of adding the sodium sulphide, and the reading remains steady for a few minutes. Nothing is gained by using gum arabic pretreated with a phosphate solution. The absorption is linear up to at least 1 mg. of cadmium in 50 ml. If the reading shows more than this, repeat with a smaller aliquot. If 10 ml. will be too much, transfer a suitable aliquot to another 100 ml. flask and make up to the mark with the ammonium chloride-phosphate solution.

The colour increases in intensity with increasing alkali up to 4 ml. of 10% caustic soda per 50 ml., and thereafter is constant. Up to 3 mg. of zinc do not interfere. More has not been tried, as 3 mg. is several times as much as it should be possible to have present.

Calibration was effected with a solution containing 80 mg./litre of cadmium, made by dissolving cadmium sulphate in the ammonium chloride-phosphate solution. A 10 ml. portion of this solution is read as well as the blank with each batch of determinations.

Test of the Method

Solutions

Zinc Sulphate—Aqueous solution of zinc sulphate containing 220 g./litre of $ZnSO_4$. $7H_2O$. 100 ml. of this solution contains 5 g. of zinc, equivalent to 30 ml. of 5 N sulphuric acid.

Cadmium Sulphate—Aqueous solution of cadmium sulphate, containing 0·5 g./litre of cadmium. 1 ml. of this solution represents 0·01% of cadmium in 5 g. of zinc.

In all cases, 20 ml. of 5 N sulphuric acid, 5 ml. of N/50 nitric acid, 100 ml. of the zinc sulphate solution, 15 ml. of the thioacetamide solution and, of the cadmium sulphate solution, the amount equivalent to the percentage of cadmium shown in Table I, were made up together to 250 ml. Where the aliquot is shown in the table as "40/100" it is measured in the cylinder; otherwise it is pipetted.

This is the whole of a single batch of determinations completed in two and a half days, using the same two half-litre flasks.

TABLE I

Cadmium Taken (%)	Aliquot	Cadmium Found (μg.)	Cadmium Found (%)
0·03	40/100	579 568 568	0·029 0·0284 0·0284
0·13	15/100	972 969 963	0·129 0·129 0·128
0·25	25/400	765 765	0·245 0·245

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D.S.I.R.'s New Five-Year Plan

EXPENDITURE on research by the Department of Scientific and Industrial Research will be nearly doubled in the next five years. Under its second five-year plan, for the period 1959–64, approximately £61 m. will be made available to the Department, compared with £36 m. for the first quinquennium, which ends on March 31st, 1959. Expansion will continue steadily throughout the period, and for the year 1963–64 expenditure is planned to reach about £14 million. This figure does not include certain items, the largest of which is the British contribution to the European Organisation for Nuclear Research (C.E.R.N.) which will continue to be financed outside the five-year plan.

The largest expansion is planned to take place in the field of scientific grants to the universities. Post-graduate awards to students will be increased by about 10% each year until in 1963–64, it is hoped, some 3,800 students will be receiving D.S.I.R. grants for research training. In the same year, it is expected that D.S.I.R. support for special research in the research departments of universities will be operating on a scale of about £1¾ million per annum.

In support of additional research carried out in the Department's own laboratories, expansion of staff at the rate of about 6% per annum is included in the plan. Grants to the Research Associations will also be increased to over £2 million per annum by the end of the period. At present there are 49 organisations in the D.S.I.R. scheme. The Council for Scientific and Industrial Research will continue its policy of encouraging industry to bear an increasing proportion of the total cost. It may be expected, therefore, that the actual expansion of the R.A movement will be proportionately greater than the increase in Government grant It has also been decided to devote much more attention and more money to ensure that the results of scientific research are known and applied.

It is also proposed that the Ministry of Works will increase its rate of expenditure on behalf of D.S.I.R., so as to provide buildings and equipment for the increased staff of D.S.I.R. laboratories. The works programme includes the provision of a new laboratory at Crowthorne, Berkshire, to rehouse the Road Research Laboratory, which at the moment occupies two separate sites a few miles apart, one at Harmondsworth, Middlesex, and the other at Langley, Bucks. The new Road Research Laboratory will include an experimental road system.

Vacuum Fusion Gas Analyser

WILD-BARFIELD Electric Furnaces, Ltd., announce that the well-known NRC Type 912 vacuum fusion gas analyser for the determination of oxygen, nitrogen and hydrogen in metals is now available as a British built unit. Over two hundred of these equipments are in operation, and it is of interest that, because of the ability of type 912 to analyse very small samples, only a 3·5 kW. induction heating generator is employed. A demonstration equipment has been installed at Elecfurn Works, Watford, where by prior appointment prospective customers may witness a complete analysis.

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The 22nd annual general meeting of Hale and Hale (Tipton) Limited was held on December 18 at Dudley, Mr. R. C. Leppington (Vice-Chairman and Managing Director) presiding in the unavoidable absence of the Chairman, Mr. W. Edgar Hale, M.I.Mech.E.

The following is an extract from the Chairman's circulated review :

I would like to emphasise at once that the year has been a most difficult and disappointing one.

The Consolidated Trading Profit for the year amounts to £93,689, as compared with £96,342 for the previous year. Taxation requires £22,638, and, after various adjustments, there remains a consolidated Net Profit of £18,884, as compared with £26,701.

The past twelve months' working has been extremely difficult, although the car industry has kept up remarkably well. Over the year there was a considerable falling off in business generally, due in a large measure to the credit squeeze, bringing about stock reductions and cuts in delivery dates by customers. Since the Suez crisis there was a sharp recession in the commercial vehicles industry, but of late there has been some improvement, and the future looks more promising.

Today, the accepted standards called for by industry are higher than ever, and continued efforts are being made to meet such demands by the installation of special finishing plant. Indeed, your Board's attention is constantly directed towards research into possible improvements in our methods and equipment, and we have every reason to be satisfied with their efforts in that important direction.

A careful watch is at all times kept on any new possibility for the use of our materials, and the amount of development going on at present is most encouraging.

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J. & J. WHITEHOUSE (TIPTON) LIMITED : This Subsidiary, trading under the name of " Phoenix " and producing cast iron holloware for export, continues to hold its own.

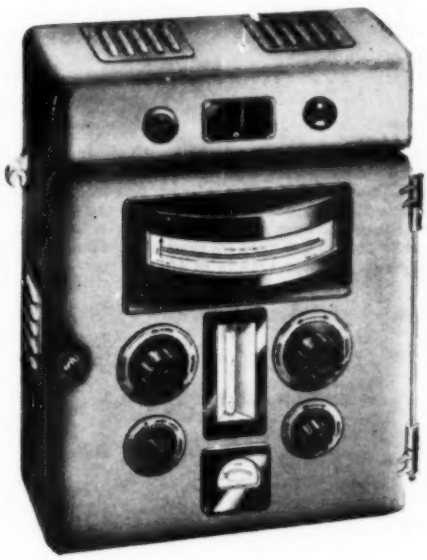
HALE ENAMELLERS LIMITED : I am pleased to report a much brighter outlook in the affairs of this Subsidiary than has appertained for a long time.

J. WAKEFIELD & SONS, LIMITED : This company is our latest Subsidiary and it manufactures a variety of paraffin heating and lighting appliances. A great amount of reconstruction was necessary and its future prospects are much brighter.

A rough estimate of the percentage of our output exported would, I think, be about 60%, and with a turnover such as your company enjoys, this represents a figure of no mean importance.

I think that world trade will expand generally, and particularly in the case of our own country; the future should be bright provided our costs of production can be kept around present-day values.

The report was adopted.



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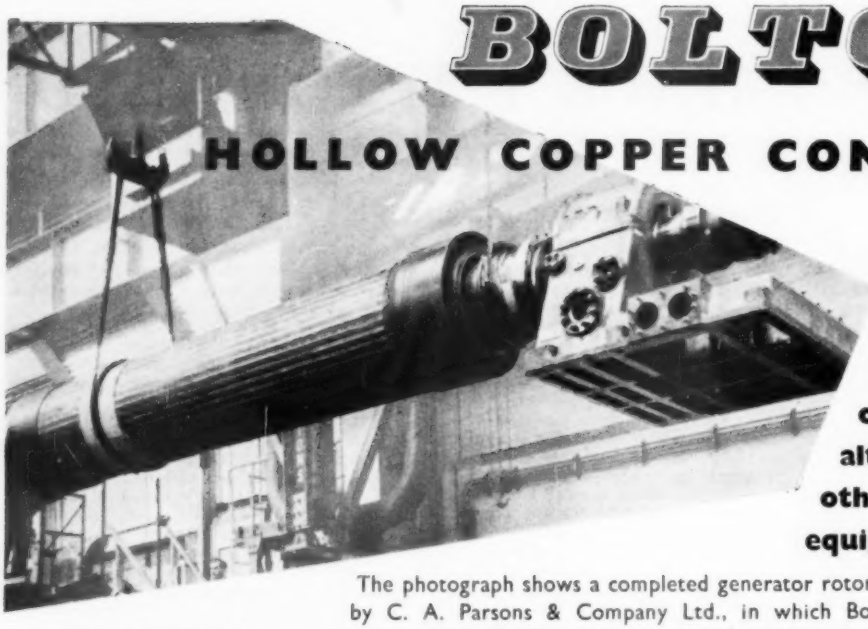

Photograph by courtesy of C. A. Parsons & Co. Ltd.,

The photograph shows a completed generator rotor manufactured by C. A. Parsons & Company Ltd., in which Bolton's hollow copper conductors have been used in the end windings. The rotor is being removed from the high speed generator which is part of a 200 MW cross-compound turbo-generator for the Richard L. Hearn generating station, Toronto, Canada.

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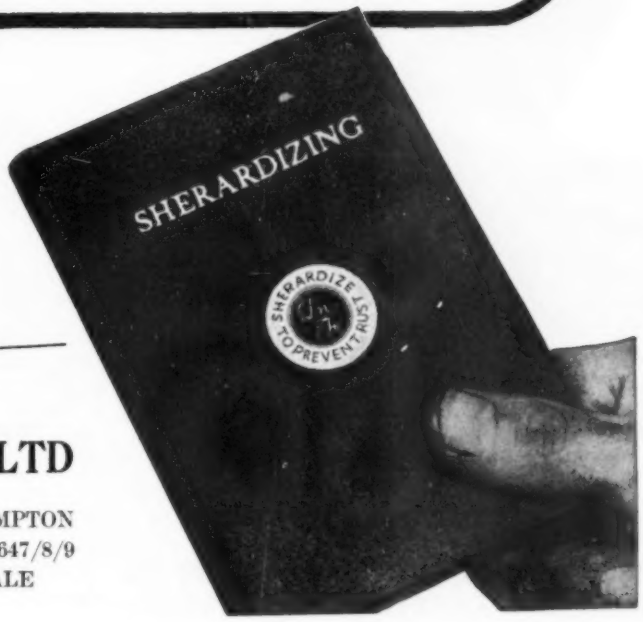

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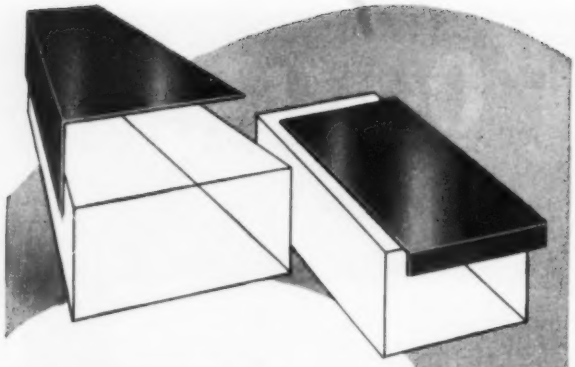

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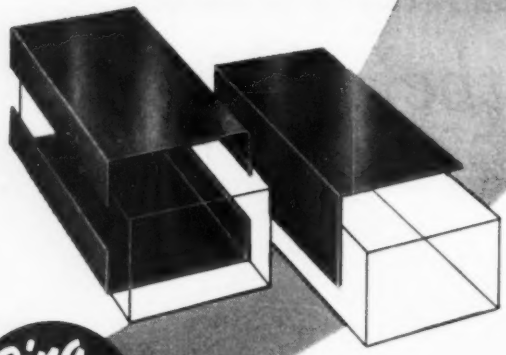

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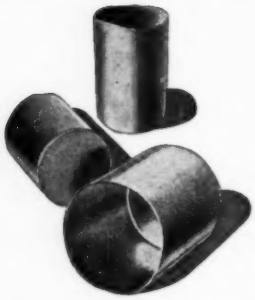

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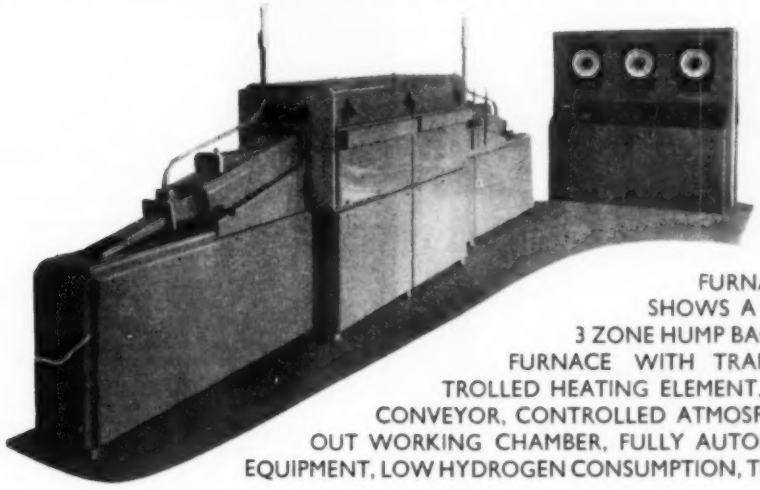

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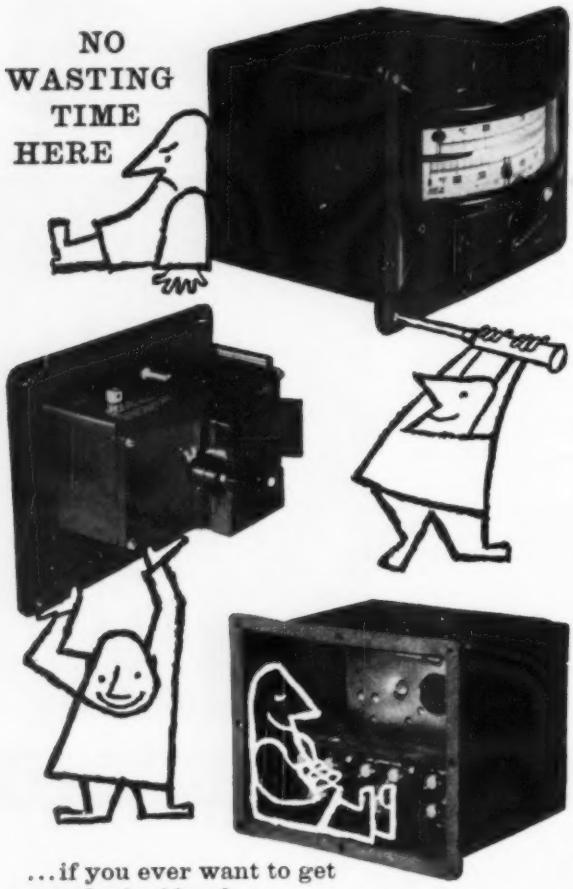

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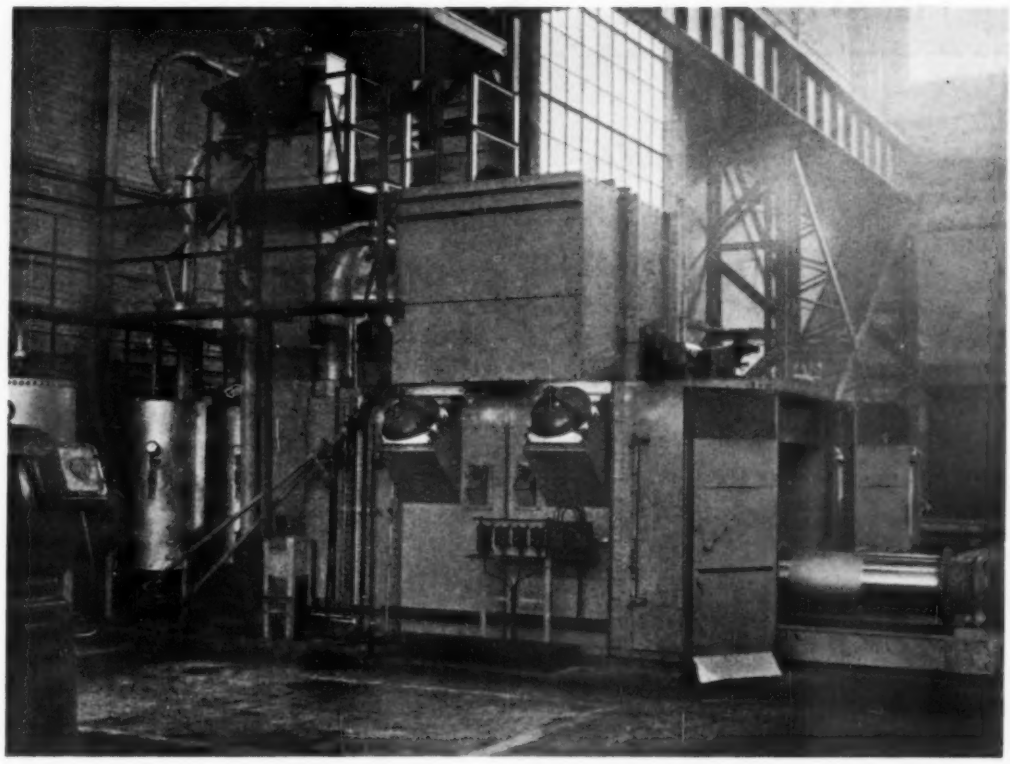

GRIT BLAST PLANT FOR PRODUCING MATT FINISH ON COLD REDUCTION PLANT ROLLS

The photograph is of a SHOT BLAST & DUST EXTRACTION PLANT *taken by kind permission of the* STEEL COMPANY OF WALES *at their* TROSTRE WORKS, LLANELLY, *one of the most modern in the world for the production of tin plate. After the rolls have been ground, the shot blasting operation effects a slightly roughened and uniform surface on the rolls in the* No. 1 STAND *of the* 2-STAND TANDEM TEMPER MILLS.

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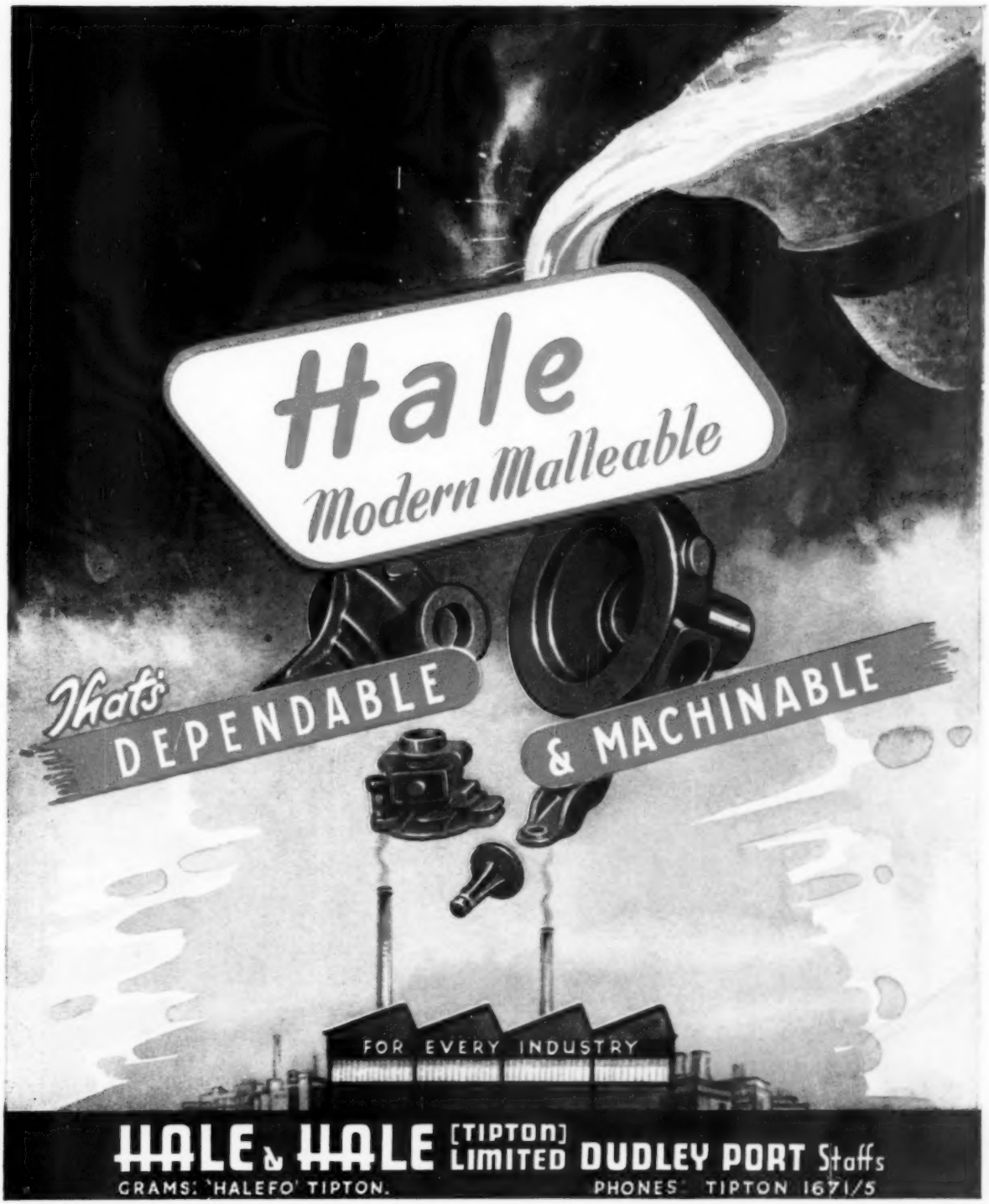

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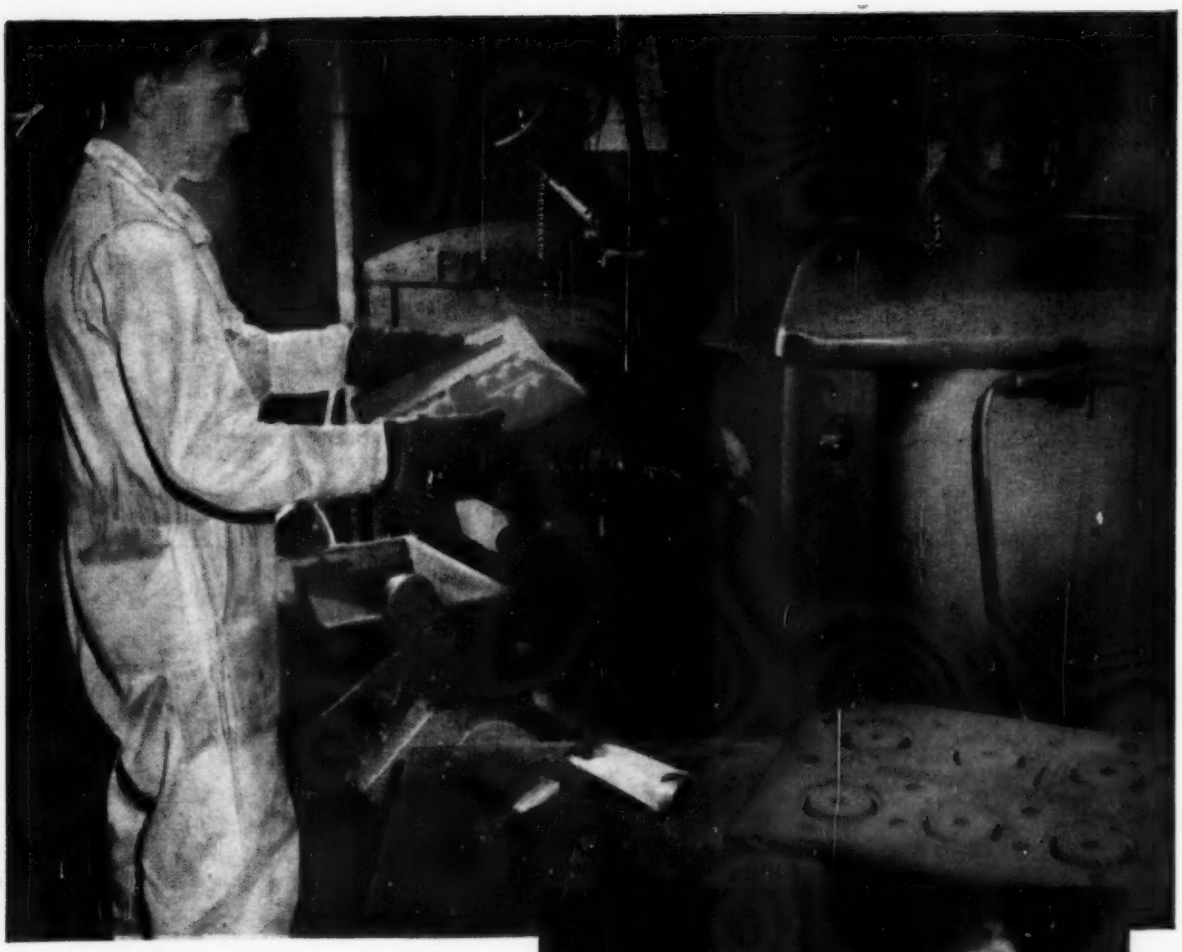

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